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MULTIMEDIA COMPUTER-BASED TRAINING AND LEARNING:
THE ROLE OF REFERENTIAL CONNECTIONS
IN SUPPORTING COGNITIVE LEARNING OUTCOMES

by

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A dissertation proposal submitted in partial fulfillment of the requirements
for the degree of Doctor of Philosophy
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ABSTRACT

Multimedia theory has generated a number of principles and guidelines to support computer-based training (CBT) design. However, the cognitive processes responsible for learning, from which these principles and guidelines stem from, are only indirectly derived by focusing on cognitive learning outcome differences. Unfortunately, the effects that cognitive processes have on learning are based on the assumption that cognitive learning outcomes are indicative of certain cognitive processes. Such circular reasoning is what prompted this dissertation. Specifically, this dissertation looked at the notion of referential connections, which is a prevalent cognitive process that is thought to support knowledge acquisition in a multimedia CBT environment. Referential connections, and the related cognitive mechanisms supporting them, are responsible for creating associations between verbal and visual information; as a result, their impact on multimedia learning is theorized to be far reaching. Therefore, one of the main goals of this dissertation was to address the issue of indirectly assessing cognitive processes by directly measuring referential connections to (a) verify the presence of referential connections, and (b) to measure the extent to which referential connections affect cognitive learning outcomes. To achieve this goal, a complete review of the prevalent multimedia theories was brought fourth. The most important factors thought to be influencing referential connections were extracted and cataloged into variables that were manipulated, fixed, covaried, or randomized to empirically examine the link between referential connections and learning. Specifically, this dissertation manipulated referential connections by varying the temporal presentation of modalities and the color coding of instructional material. Manipulating the temporal presentation of modalities was achieved by either presenting modalities simultaneously or sequentially. Color coding

manipulations capitalized on pre-attentive highlighting and pairing of elements (i.e., pairing text with corresponding visuals). As such, the computer-based training varied color coding on three levels: absence of color coding, color coding without pairing text and corresponding visual aids, and color coding that also paired text and corresponding visual aids. The modalities employed in the experiment were written text and static visual aids, and the computer-based training taught the principles of flight to naïve participants. Furthermore, verbal and spatial aptitudes were used as covariates, as they consistently showed to affect learning. Overall, the manipulations were hypothesized to differentially affect referential connections and cognitive learning outcomes, thereby altering cognitive learning outcomes. Specifically, training with simultaneously presented modalities was hypothesized to be superior, in terms of referential connections and learning performance, to a successive presentation, and color coding modalities with pairing of verbal and visual correspondents was hypothesized to be superior to other forms of color coding. Finally, it was also hypothesized that referential connections would positively correlate with cognitive learning outcomes and, indeed, mediate the effects of temporal contiguity and color coding on learning. A total of 96 were randomly assigned to one of the six experimental groups, and were trained on the principles of flight. The key construct of referential connections was successfully measured with three methods. Cognitive learning outcomes were captured by a traditional declarative test and by two integrative (i.e., knowledge application) tests. Results showed that the two multimedia manipulation impacted cognitive learning outcomes and did so through corresponding changes of related referential connections (i.e., through mediation). Specifically, as predicted, referential connections mediated the impact of both temporal contiguity and color coding on lower- and higher-level cognitive learning outcomes. Theoretical

and practical implications of the results are discussed in relation to computer-based training design principles and guidelines. Specifically, theoretical implications focus on the contribution that referential connections have on multimedia learning theory, and practical implications are brought forth in terms of instructional design issues. Future research considerations are described as they relate to further exploring the role of referential connections within multimedia CBT paradigms.

I would like to dedicate this dissertation to:

My wonderful, supporting and loving wife, Shannon Amerilda Scielzo,
who has always been present, for all the ups and downs.

My beautiful and inspiring daughter, Jade Amerilda Scielzo,
who has enriched my life beyond anything I thought was possible.

My dear mother, Sophie Delannoy, whose unwavering optimism, love,
and support taught me to never quit against any odds.

My caring father, Vito Scielzo, who has given me the foundation, structure,
and morals to become the man that I am today.

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LIST OF ABBREVIATIONS

A / V	Audio / Visual
ATI	Aptitude-Treatment Interaction
AVI	Audio-Video-Interleaved
CBDF	Computer-Based Design Factor
CBT	Computer-Based Training
CTML	Cognitive Theory of Multimedia Learning
CV	Covariate Variable
DCT	Dual Coding Theory
DLH	Deep Level Help
DV	Dependent Variable
HIP	Human Information Processing
IDF	Individual Difference Factor
IV	Independent Variable
LTM	Long-Term Memory
RC	Referential Connection
SLH	Surface Level Help
SOI	Selecting, Organizing, Integrating
TPL	Team Performance Laboratory

CHAPTER 1: THEORETICAL FRAMEWORK AND RESEARCH PLAN FOR INVESTIGATING REFERENTIAL CONNECTIONS IN A MULTIMEDIA COMPUTER-BASED TRAINING ENVIRONMENT

Over the past few decades, multimedia learning theories have generated a number of principles and guidelines to facilitate the design of computer-based training (CBT) material. The impact these principles and guidelines have is widespread and far-reaching due to the prevalent use of CBT in academia, government, and industry (e.g., Najjar, 1998). Specifically, in academia, 90% of all universities with more than ten-thousand students employ some variation of e-learning (e.g., Galvin 2003), which falls under the umbrella of CBT and typically consists of online instructional material specially structured to fit the medium (e.g., Hirumi, 2002). The military and other government organizations also rely more on CBT as an effective method of training (e.g., Cuevas, Fiore, Bowers, & Salas, 2004; Fiore, Cuevas, Scielzo, & Salas, 2002). Finally, in business organizations, the prevalence of CBT as a means to train the workforce is exponentially increasing, with a national average of 16% at the beginning of this decade (e.g., Galvin 2003). Therefore, following accurate multimedia principles in the design of CBT is essential.

The theoretical foundations of multimedia principles and guidelines are based on cognitive processes that have rarely been directly measured; hence, their purported impact on learning, training, and overall CBT design is, at best, only indirectly supported, and based on the assumption that learning or training outcomes are indicative of corresponding underlying cognitive processes. One of these foundational elements of multimedia theory is the notion of referential connections (RCs). In short, RCs can be defined as the working memory process and outcome of integrating audio and visual information together. The process of integration – as it

relates to RCs – refers to the encoding into long-term memory (LTM) the conceptual understanding of audio and visual information, and how they relate. For example, a trainee that is learning about the “rudder” concept from the aviation domain, which is presented in a CBT with text or narration, and also with a visual description (e.g., pictures, animations, etc.). The specific information-processing steps are detailed in later sections; however, simply put, the process of understanding and encoding that audio (i.e., text or narration) and visual (e.g., animations, visual aids, etc.) information both discuss the concept of the rudder (i.e., creating a conceptual link between information from the audio and visual modalities), and transferring that connection into LTM, basically reflects the process of RC creation.

Problem Statement

According to many multimedia theories, proper integration between working memory modes (i.e., verbal and visual modes) is pivotal for successful learning. However, this positive effect on learning is based on (a) the assumption that linkages between visual and audio information occur, and (b) the assumption that learning gains are associated – in part – with RCs. This dissertation remediates this lack of direct RC evidence by (a) providing a systematic approach to isolate most computer-based design and individual differences factors thought to influence RCs, (b) directly assessing RCs to gauge the extent to which RCs impact learning, and (c) studying RCs under conditions that either facilitate or hinder their development.

Scope of Research

This first chapter provides a comprehensive theoretical overview of the cognitive processes involving RCs, and to isolate most factors that are thought to influence such RCs within a multimedia CBT. In this chapter, two main factor categorizations are brought forth: (a)

computer-based design factors and (b) individual differences factors. This categorization reflected a systematic effort to catalog factors that can influence RCs, eventually leading to this dissertation's experiment by providing factors that were subsequently manipulated, fixed, covaried, or randomized. The variables chosen to be manipulated in this dissertation were determined by (a) level of importance, (b) practicality, and (c) interest. Overall, this process of factor categorization was necessary to bring forth a comprehensive view on referential connections and the manner in which they can impact the learning process. To achieve this aim, this chapter is divided into three (3) sections: (a) a theoretical overview of RCs in the multimedia literature, along with associated factors, (b) an integrated theoretical multimedia framework, and (c) RC factor categorization and rationale that leads into the proposed experiment for this dissertation.

Referential Connections in the Multimedia Literature

Referential Connections and Paivio's Dual Coding

The notion of RCs in relation to multimedia learning first emerged with Paivio's (e.g., 1978, 1986, 1991) Dual Coding Theory (DCT). DCT was first to recognize that two systems, verbal and nonverbal, were responsible for differentially processing perceived sensory information. Overall, the main contribution of DCT was that encoding information via two systems is superior, in terms of retrieval, when compared to encoding via only one system.

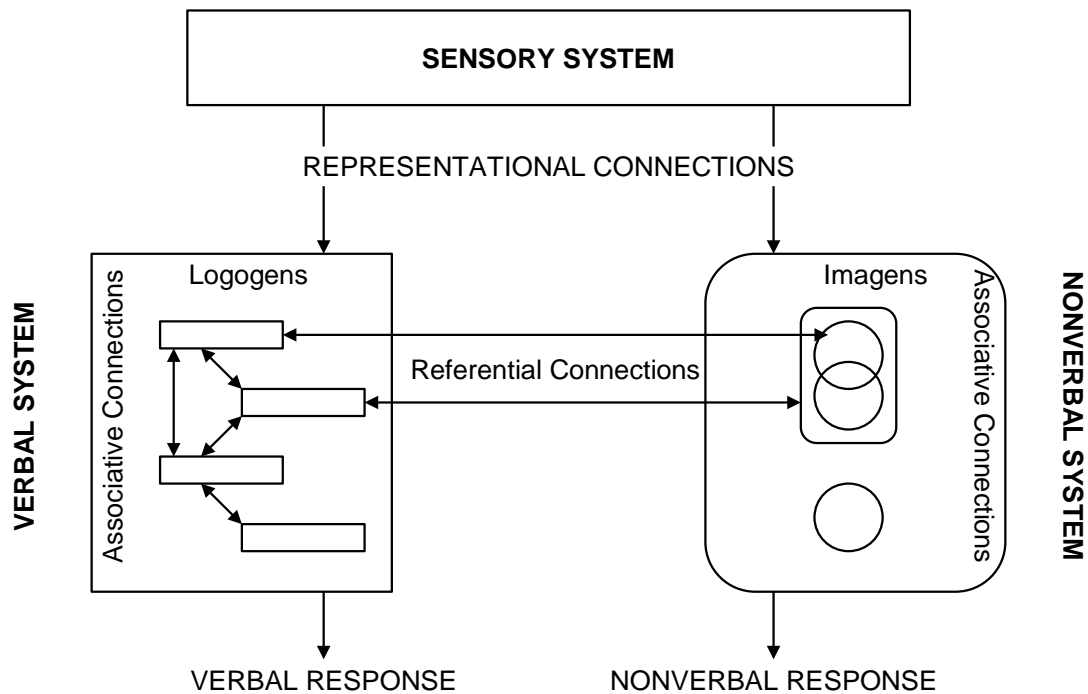


Figure 1. DCT model adapted from Paivio (1986, p. 67) illustrating the verbal and nonverbal systems, as well as the three types of connections: Representational, associative, and referential.

DCT proposed that, along with the two memory systems, three main processes connected information together: Representational connections¹, associative connections, and RCs (e.g., Paivio, 1986; Sadoski & Paivio, 2001). Figure 1 illustrates a general model of DCT.

First, *representational connections* represent the process of attributing meaning to the perceived information (i.e., information in the sensory system). Specifically, the connection represents linking specific sensory information with *logogens* and *imagens*, which represent, respectively, the smallest verbal and nonverbal information units. In other words, logogens and imagens represent conscious representations of information within the sensory system. This

process is referred to as *representational processing*. Next, *associative connections* represent the linking of logogens with other logogens, and imagens with other imagens. Specifically, logogens within the verbal system connect sequentially and hierarchically into informational units, while imagens within the nonverbal system connect in a nested or parallel manner into information units (e.g., Paivio, 1991; Sadoski, & Paivio, 2001). The successive nature of logogens associations, compared to the parallel nature of imagens associations is important because, according to Paivio (1986) it reflects the natural constraints of the perceived sensory information; that is, verbal information is processed sequentially (e.g., reading or hearing text), and nonverbal information is processed largely synchronously (e.g., looking at a picture or animation). Specific implications in relation to RCs are detailed in another section of this dissertation. Overall, *associative processing* represents the organizing of verbal and non-verbal information units within a verbal and nonverbal system, respectively, and these units can vary in size and complexity (e.g., Paivio, 1991).

RCs correspond to the linking of logogens with imagens. In Paivio's work (1978, 1986, 1991), a RC occurs when a logogen elicits an imagen. For example, a concrete word such as 'airplane' may elicit a nonverbal representation of that word, and vice versa. A RC may not occur for abstract information. Generally, DCT stresses the importance of *referential processing* since information that has been encoded both verbally and nonverbally can be retrieved more easily than information encoded via only one modality. This benefit is at the essence of dual-coding.

¹ The term 'connection' and 'interconnection' are both used interchangeably in Paivio's literature. In this dissertation, the term 'connection' is used for consistency across literature.

Overall, in terms of multimedia CBT learning, supporting each of the three processes that DCT isolates (i.e., representational, associative, and referential) would theoretically improve the strength of their respective connections. Indirect evidence abounds in the multimedia literature, indicating that CBTs employing two modalities (i.e., either text and visual aids, or narration and visual aids) are better than CBTs employing one modality in terms of overall cognitive learning outcomes (e.g., Igo, Kiewra, & Bruning, 2004; Fiore, Cuevas, & Oser, 2003; Kalyuga, Chandler, & Sweller, 2004; Lewandowski & Kobus, 1993; Mayer & Andersen, 1991, 1992; Moreno & Mayer, 2002; Michas, & Berry, 2000; Tindal-Ford, Chandler, & Sweller, 1997). However, DCT has three main drawbacks when looking at RCs in a multimedia CBT paradigm. First, DCT focuses more on isolated units of information as opposed to a larger domain of information to be learned. Second, DCT does not clearly indicate what impact on learning each interunit connection has (i.e., associative and referential connections). Finally, DCT does not clearly distinguish between visual text and narration (i.e., audio text) which are perceived via different sensory mechanisms, but processed within the same working memory mode. Table 1 summarizes the main factors thought to influence RCs according to DCT.

Table 1: *RC computer-based design factors according to DCT*

RC computer-based design factors	Possible manipulation	Relationship to RCs
Information units	Small versus large, and simple versus complex	Size and complexity may negatively impact learning
Information presentation	Abstract versus concrete	Logogens and imagens are more easily connected and encoded when they represent concrete information

Referential Connections and Mayer's Cognitive Theory of Multimedia Learning

Cognitive Theory of Multimedia Learning (CTML) was developed to address the need to better understand how to design multimedia instructional material that would favor knowledge

retention (e.g., Mayer, 2001). CTML is based on empirically validated multimedia learning principles within a working memory framework.

It appears that CTML evolved in part to expand the reach of DCT to more global learning paradigms. A shift in naming convention occurred from DCT to CTML. Specifically, DCT's associative connections (i.e., within-mode connections) are referred to as representational connections in CTML. It is not clear why the change in terminology occurred, especially since terms seemed to have been interchanged. However, in spite of change in terminology, Mayer and Anderson (1991, 1992) theorized that while representational connections' impact on learning is more at the surface level, the creation of RCs enables problem solving; thereby emphasizing the importance of designing instructional material supporting RCs.

An important contribution of CTML regards what Mayer and Sims (1994) determined to be an extension of DCT: dual coding is superior when textual information (written or narrated) and visual information are in close proximity as opposed to being spatially separated. This concept turned into the spatial contiguity principle and has been investigated via three main multimedia design paradigms: (a) Annotated illustrations (e.g., Mayer, Bove, Bryman, Mars & Tapango, 1996; Mayer, Steinhoff, Bower & Mars, 1995), which are composed of static images with embedded key terms, while a text caption lays below the overall image, (b) narrated animations (e.g., Mayer & Anderson, 1991, 1992; Mayer & Moreno, 1998), which comprise an animation with respective narration (without any text) and a text caption below it, and (c) integrated text (Mayer & Anderson, 1991, 1992; Mayer & Moreno, 1998), which is composed of either a static image or an animation, along with an embedded text caption within the image or animation. Overall, the learning benefits of integrating text and visual aids are assumed to be due to the creation of stronger RCs when spatial proximity between the two modalities is maximized.

Another contribution of CTML relates to the *modality principle* (e.g., Mayer, 2001; Moreno, 2006; Moreno & Mayer, 1999) which parallels DCT by identifying the superiority of parallel processing; specifically, the superiority of using narration and visual aids as opposed to text and visual aids (e.g., Mayer & Anderson, 1991, 1992; Mayer, & Moreno, 1998; Mayer, Moreno et al., 1999; Mayer and Sims, 1994; Moreno & Mayer, 1999; Mousavi, Low, & Sweller, 1995). This superiority is theorized by CTML to be due to the lack of split-attention that is required by a text-plus-visual-aid format. That is, even though text and visual aids are processed in parallel (in the same manner as narration and visual aids), the acquisition of text and visual information happens sequentially. Recently, multimedia research (e.g. Kalyuga et al., 2004; Moreno, 2006) has shown that the modality principle seems to be moderated by the training pace, which can be either self-paced or system-paced. Specifically, the differences between a text and visual aids design versus a narration and visual aid design are more pronounced when the pace is dictated by the system, while those differences tend to be less pronounced when the pace is controlled by the learner. In relation to RCs, it is assumed that RC creation can suffer from the split-attention induced by a text-plus-visual-aids design.

CTML offers another factor that can affect RCs. This factor is related to the presence or absence of extraneous material. Specifically, the *coherence principle* (e.g., Mayer, 2001) indicates that any information (e.g., environmental sounds, narration, text, or visual aids) should be removed if it is not directly related to the material to be learned. Research has shown that the addition of extraneous text and / or images – also defined as seductive details – is detrimental to knowledge acquisition (e.g., Harp & Mayer, 1998), as is the addition of irrelevant sounds (e.g., Moreno & Mayer, 2000). Under CTML, extraneous material would distract the learner (e.g., the

learner may not readily know which verbal and visual information units to link together), and unnecessary, irrelevant, or erroneous RCs could arise, thereby, negatively affecting learning.

Finally, CTML brings forth the notion that verbal and visual information can be presented in a CBT either simultaneously or successively. Specifically, the *temporal contiguity principle* indicates that cognitive learning outcomes are greater when verbal and visual information are presented together. Theoretically, a simultaneous presentation allows for stronger RCs to occur when compared to a successive presentation (e.g., Mayer & Anderson, 1991, 1992; Mayer, Moreno, Boire, & Vagge, 1999). Table 2 summarizes the main factors thought to influence RCs.

Table 2: RC computer-based design factors according to CTML

RC computer-based design factors	Possible manipulation	Relationship to RCs
Spatial contiguity	Integrated versus non-integrated text and visual aids	- Integrated: leads to strong RCs - Non integrated: leads to weak RCs
Modality principle	narration and visual aids versus text and visual aids (parallel versus successive information acquisition)	- Parallel acquisition: leads to strong RCs - Sequential acquisition: leads to weak RCs
Training pace	learner-paced versus system-paced	- Learner-paced: leads to strong RCs - System-paced: leads to weak RCs
Coherence principle	Presence or absence of extraneous sounds, visual aids, and written or narrated text	- Presence of extraneous material: leads to weak RCs - Absence of extraneous material: leads to strong RCs
Temporal contiguity	Simultaneous versus successive presentation of verbal and visual information	- Simultaneous: leads to strong RCs - Sequential: leads to weak RCs

Referential Connections and Seufert’s “Coherence Formation”

According to Seufert and Brunken (2004, 2006), the process of multimedia learning can be explained by the theoretical framework of “coherence formation.” Coherence formation indicates the manner in which instructional material in a multimedia paradigm is integrated,

which can be either local or global. Local coherence basically indicates the process of creating referential connections between and within text and pictures' mental representations (i.e., Paivio's representational units and interunit connections). Global coherence refers to the structure mapping of mental representations of these local connections. Unfortunately, it appears that in this framework, the distinction between interunit connection type (i.e., associative and referential) is lost, and RCs reflect both within and between type of connections. Nonetheless, the coherence formation framework brought forth an important dichotomy in techniques thought to help the creation local and global coherence: Surface level help (SLH) and deep level help (DLH).

SLH is a conglomerate of computer-based techniques aimed at improving local coherence, and hence, improving RCs. These techniques are not all unique to the coherence formation framework. Color coding, for example, refers to the use of colored text to highlight important key terms with their respective visual counterparts (e.g., Kalyuga, Chandler, & Sweller, 1999; Kozma, 2003; Tabbers, Martens & van Morrienboer, 2004). Another SLH technique is "dynamic linking" (e.g., Bodemer, Ploetzner, Feuerlein & Spada, 2004). This technique reflects the ability from the user to modify parameters and to see changes in real time (e.g., observing changes in a graph after modifying corresponding values). A final technique used in the coherence formation framework is referred to as 'inter-textual hyperlinks' (e.g., Brunken, Seufert, Zander, 2005). This technique reflects the use of hyperlinked key words, and when the hyperlink is activated, an arrow appears, relating the word with its visual counterpart.

DLH represents techniques that would benefit global coherence formation. These techniques, such as text prompts that indicate how various taught concepts are related together

(e.g., Seufert, 2003), are not directly related to RCs, but illustrate the importance of integrating units of information (e.g., Paivio, 1991) together.

Overall, the contribution of the coherence formation framework is important in the domain of multimedia computer-based training paradigms since it brings forward SLH and DLH techniques. Specific to RCs, SLH is composed of techniques that are thought to aid the process of creating RCs. Table 3 summarizes the main factors thought to influence RCs.

Table 3: *RC computer-based design factors according to the ‘coherence formation’ framework*

RC computer-based design factors	Possible manipulation	Relationship to RCs
Color coding	Presence or absence of color coding	- Presence: leads to strong RCs - Absence: leads to weak RCs
Dynamic linking	Presence or absence of dynamic linking	- Presence: leads to strong RCs - Absence: leads to weak RCs
Inter-textual hyperlinks	Presence or absence of inter-textual hyperlinks	- Presence: leads to strong RCs - Absence: leads to weak RCs

Other Relevant Factors within the Multimedia Literature

In this section, the following factors reflect other main computer-based design factors (i.e., techniques that are thought to influence RCs) as well as individual differences factors that are thought to moderate the relationship between design factors and RCs. These two types of factors are summarized by Table 4 and Table 5 respectively.

Table 4: RC computer-based design factors from the literature at large

RC computer-based design factors	Description and Literature	Possible manipulation	Relationship to RCs
Congruence principle	Content and format of the graphics should correspond to the content and format of the concepts to be conveyed. For example, using animations to illustrate concepts that change over time. Congruent graphics lead to better learning retention as opposed to non-congruent graphics (Tversky & Morrison, 2002)	Congruent versus non congruent graphics	- Congruent: leads to strong RCs - Non congruent: leads to weak RCs
Domain	This factor is thought to influence external validity concerns (i.e., whether causal relationships hold true across domains). Domain seems to be also having a moderating effect on learning (e.g., De Westelinck, Valcke, De Craene, Kirschner, 2004).	Test various orthogonal domains	Since domain moderates learning, the same moderation may apply to RC creation
Personalization effect	personalized text would include “yours” instead of “the” for non-personalized (e.g., Mayer, Fennell, Farmer & Campbell, 2004; Moreno & Mayer, 2004)	Personalized versus non-personalized text	Personalizing text helps learning
Dynamic visualizations	The theoretical benefit of using dynamic displays to convey information (e.g., Hegarty, 2004; Narayanan & Hegarty, 2000; Schmidt-Weigand, 2005).	Static versus dynamic displays	N/A
3D visualizations	The use of three-dimensional visualization techniques to allow learners to manipulate objects (e.g., Huk, 2006; Wu, Krajcik & Soloway, 2001)	2D versus 3D	N/A
Dynamic changes	Said about any visual changes aimed at capturing attention (Yantis, 1998). Effective dynamic changes are thought to improve learning by minimizing workload, thereby improving RC creation	Presence or absence of dynamic change	- Presence: leads to strong RCs - Absence: leads to weak RCs
Cueing effect	Cueing effect represents any visual method (e.g., color coding) aimed at capturing the attention to improve text / visual aid links; thereby improving RCs (e.g., Tabbers, Martens & van Merriënboer, 2004)	Presence of absence of inter-textual hyperlinks	- Presence: leads to strong RCs - Absence: leads to weak RCs

Note: N/A is used when corresponding literature does not explicitly or implicitly describes an effect on RCs

Table 5: *Individual differences factors from the literature at large*

Individual differences factors	Description and Literature	Possible manipulation	Relationship to RCs
Aging	Effects of aging in relation to computer-based training. Evidence suggests that there are no significant differences between young and elderly (e.g., Beier & Ackerman, 2005)	Young versus elderly	Chunking may be more effective with elderly, thereby facilitating RC creation
Background knowledge	level of background knowledge regarding the concepts being trained for (e.g., Chun & Plass, 1997; Lowe, 1996)	Presence or absence of background knowledge	Background knowledge may facilitate chunking, thereby facilitating RC creation
Goal orientation	training novices for high goal orientation by teaching key concepts in isolation before being training on more dynamic systems improves overall performance (Bodemer, Ploetzner, Bruchmuller & Hacker, 2005)	High versus low goal orientation	N/A
Learning styles	Learners' favoritism for a type of modality such as visualizers and verbalizers (e.g., Chun & Plass, 1997)	visualizer versus verbalizer	N/A
Spatial Ability	Spatial ability seems to differentially moderate the relationship between computer-based design factors and cognitive learning outcomes (e.g., Chun & Plass, 1997; Mayer, 2001; Scielzo, Dahan, Lopez & Stafford, 2006)	Post-hoc grouping of high versus low spatial ability learners	High spatial ability may reduce attention resources used when processing visual information, thereby improving pictorial model
Verbal ability	Verbal ability seems to be a reliable predictor of performance (e.g., Chun & Plass, 1997; Mayer, 2001)	Post-hoc grouping of high versus low verbal ability learners	High verbal ability may reduce attention resources used when processing verbal information, thereby improving verbal model

Note: N/A is used when corresponding literature does not explicitly or implicitly describes an effect on RCs

An Integrated Theoretical View of Referential Connections

This section describes the process of creating RCs within an integrated multimedia framework. This framework will draw from both Mayer's (2001) CTML model and from Wickens' (1997) human information processing model (HIP); however, the framework does not

represent a new model per se, rather, it represents an attempt at better understanding the processes leading to RCs.

The two chosen models each provide a complementary focus; that is, the CTML model focuses on working memory mechanisms, while the HIP model focuses on stages of processing and attention demands. Together, these two models should offer sufficient foundation to be able to categorize each factor thought to influence the process of RC creation. The goal is twofold: (a) to provide a common theoretical ground for all the factors mentioned in the previous sections, and (b) to allow for specific predictions to be made. Next, the two models will be reviewed in relation to the process of creating RCs.

The CTML Model

This model focuses on working memory, and how multimedia information is Selected, Organized, and Integrated (SOI), which is at the core of Mayer’s (1999b) *constructivist learning* theory (see Figure 2). Together, the SOI learning theory, which is descriptive in nature, along with the CTML instructional theory, which is prescriptive in nature, offers a global perspective on multimedia learning. This perspective is used throughout this dissertation, and is the basis for this dissertation’s multimedia framework, which is presented in the next chapter.

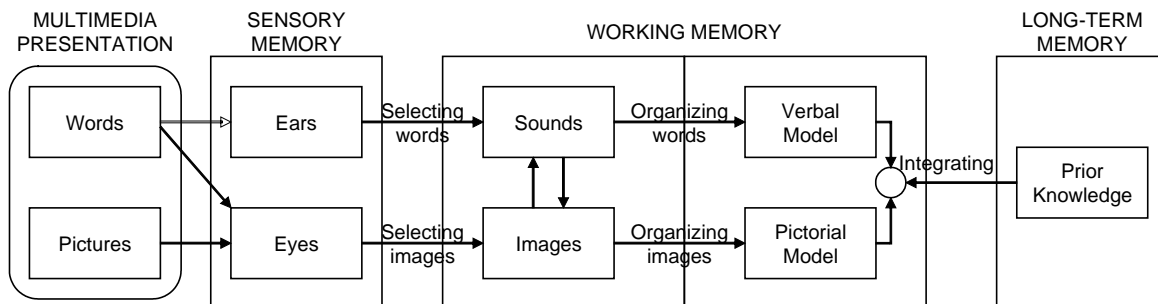


Figure 2. CTML Model, adapted from Mayer (2001)

In this model, the process of creating referential connections is inferred rather than explicit. Theoretically, RC creation occurs when information from the verbal model is integrated with information from the pictorial model (e.g. Mayer & Sims, 1994). However, in the model, the integration step does not distinguish between representational connections (i.e., connecting information within the verbal or pictorial model) and RCs; rather, it reflects the general process of knowledge acquisition. Nonetheless, this model supports the notion that RC creation is a working memory process that links meaningful verbal and pictorial information together. Specifically, before RCs can occur, perceived sounds (i.e., text or narration) and images from sensory memory are selected and moved into working memory where they are further processed and organized into a meaningful verbal and pictorial model, that is, the process of chunking individual verbal and visual information units into a larger meaningful unit. Once the information is organized, corresponding words (textual or narrated) and images can be linked into RCs during the process of integration.

This model is important in understanding RCs because it isolates several areas in which computer-based design factors can aid the process of creating RCs. Namely, factors that can assist the process of selecting, organizing, and integrating information, will, in turn, aid the process of creating RCs. Unfortunately, the main drawback of this model is that it does not adequately illustrate the manner in which information is selected, organized, and integrated; thereby, making it difficult to precisely categorize factors computer-based design factors that can aid the process of creating RCs. Furthermore, the model does not account for RCs, or any integrated material, to be transferred to long-term memory, which, in turn, can influence how information is selected and organized in the first place. The next model partly remediates to these shortcomings.

The HIP Model

The HIP (Wickens, 1997) model focuses on the successive processing of information, on distinct memory systems and the manner in which they affect information processing, and on attention resources and how they may limit information processing (see Figure 3). This model was primarily developed to account for the decision-making process and consequent physiological responses to processed information, and not specifically to account for computer-based multimedia training. Nonetheless, this model explicitly isolates the various successive steps involved in the encoding and processing of information, and how memory and attention resources are involved. This is important since it allows better understanding and categorizing of how each factor may impact the creation of RCs.

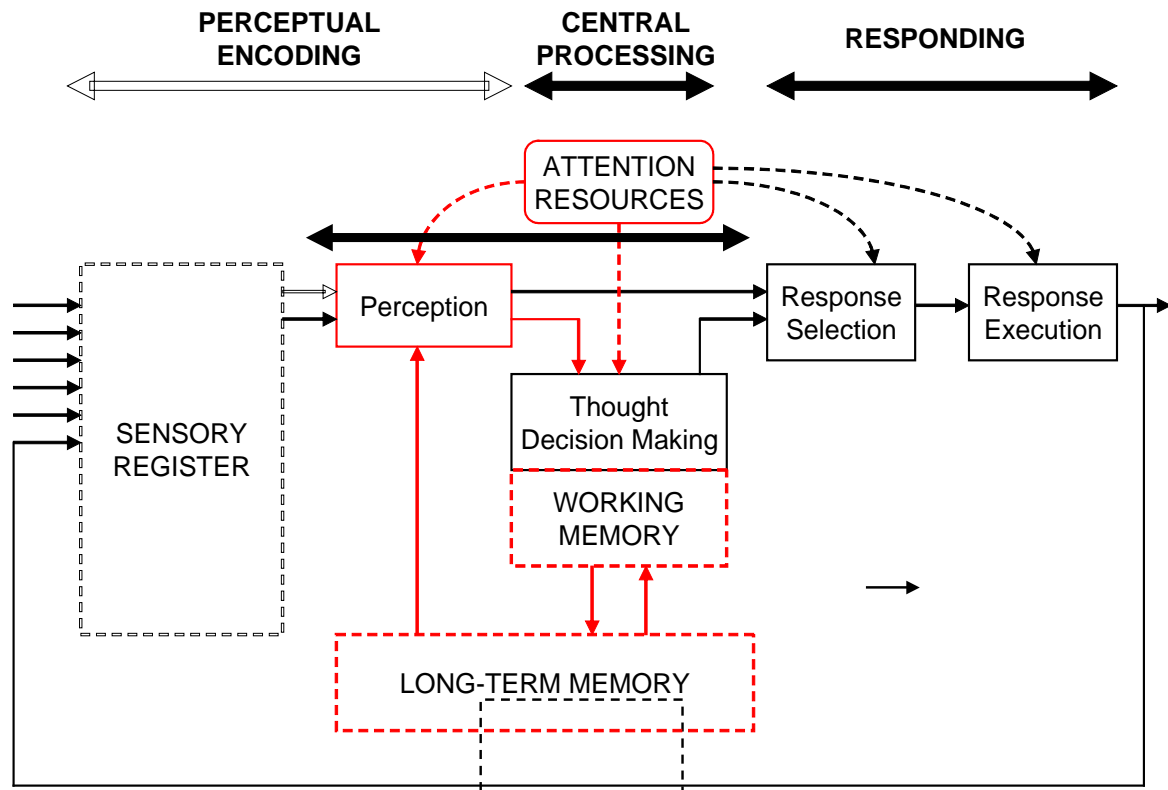


Figure 3. HIP model, with the parts involved in multimedia learning in red. Adapted from Wickens, Gordon, and Liu (1997)

A Framework of Processes

Borrowing concepts from the CTML model and the HIP model provides more insight into the three main SOI working-memory processes (i.e., selecting, organizing, and integrating information). In relation to the creation of RCs, looking at both models allows for better prediction of how a particular factor can influence RCs. Together, the two models can help determine at what level of information processing a factor thought to influence RCs exerts its influence. As a result, in order to maximize RC creation, it is necessary to use factors that can positively affect the SOI processes along with supporting attention resources and LTM. Next, a review of the SOI processes is offered when the two models are taken into consideration, which will lead a newly theoretical explanation of RCs.

Selection of information. This perceptual encoding process draws on both attention resources and long-term memory (LTM), in terms of top-down processing, in order to attribute meaning to the information. The more effective LTM top-down processing is, the less attention resources are depleted. Furthermore, during the selection process, attention resources can be further guided to specific information by using pre-attentive methods (e.g., Treisman & Kanwisher, 1998) such as color coding and animations.

Organization of information. This working-memory process is also subject to LTM in terms of top-down processing, and attention resources can be further depleted. That is, the selection process may be aided by LTM (in terms of general knowledge and domain specific knowledge) to help chunking meaningful information units together. Furthermore, similarly to the selection process, attention resources may be differentially depleted in the organization process according to the level and efficiency of LTM top-down processing. Factors that can aid

the organization process are, for example, methods that explicitly tie presented information together, such as Seufert and Brunken (2004) SLH techniques presented earlier.

Integration of information. Once the information is organized, RCs can occur. That is, organized and meaningful verbal information units can be associated with respectively organized and meaningful visual information units (e.g., Mayer & Sims, 1994; Sadoski & Paivio, 2001). Derived from the HIP model, this process uses the remaining attention resources to move organized information into LTM. Overall, the more a computer-based multimedia presentation supports the previous two processes (i.e., selection and organization), the more attention resources will be available for integration.

Referential Connections Redefined

The framework presented above isolated the main steps of information processing (i.e., selection, organization, and integration) that lead to RCs, which represent the encoding of linked audio / visual material into LTM. As a result, RCs reflect both the working memory processes (e.g., selecting, organizing, integrating) and the learning outcome (i.e., the actual LTM memory of the audio / visual connection).

Based on the multimedia literature, RCs can occur when audio and visual information is presented simultaneously. However, a more in-depth look at RCs does not preclude a successive variation. Next, the concept of RC is theoretically discussed when it occurs in a simultaneous or successive information presentation paradigm.

RCs with simultaneous A/V. This is the typical manner, described so far, in which RCs occur. Figure 4 is a simplified schematic describing this process. The Figure shows how information that has already been selected in the audio and video store gets organized, linked into RCs, and encoded into LTM with audio / visual representations. As seen in the figure, both

audio and visual information are directly processed in working memory. In terms of attention resources, depletion occurs as described in the previous sections (i.e., at the selection, organization, and integration steps).

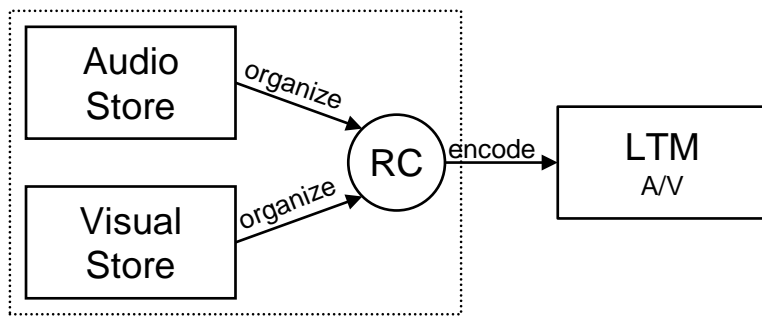


Figure 4. Illustration of the RC process, with simultaneous presentation of audio and visual information. Working memory processes are within dotted boundaries.

RCs with successive A/V. Past literature does not clearly document the specific process of RCs when audio and visual information is presented sequentially. Most literature discusses Mayer's (1999a, 2001) *temporal contiguity effect* in terms of general effect of varying modality presentation timing and how it affects knowledge retention. The notion of RCs is only addressed to explain the superiority of an audio / visual presentation when compared to presenting modalities sequentially. However, theoretically, RCs can occur when information is presented sequentially (see Figure 5).

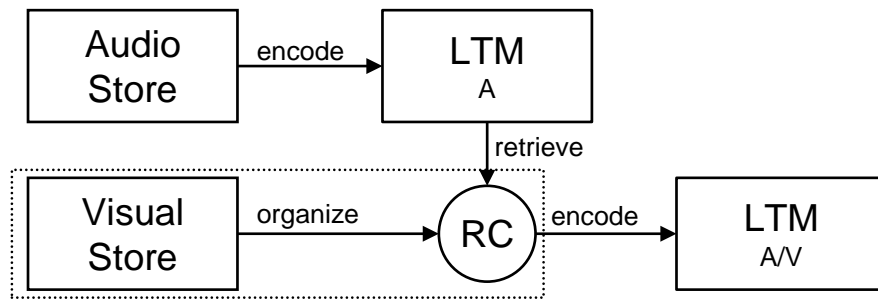


Figure 5. Illustration of the RC process, with successive presentation of audio and visual information. Working memory processes are within dotted boundaries.

The example provided in Figure 5 describes a successive multimedia CBT presentation, with audio (i.e., narration or text) presented first, followed by visual information (e.g., image, animation, etc.). When audio information is presented in isolation, only associative connections (i.e., within mode associations; not shown in figure) can be organized before they are encoded into LTM. The “A” in the LTM box refers to the fact that at that moment, only audio information units are encoded. Next, when visual information is presented, it is organized *and* corresponding audio information previously encoded into LTM can be retrieved and linked together into RCs. At that point, the newly linked audio / visual information is encoded into LTM. In terms of attention resources, the successive RC process is more demanding when compared to the simultaneous process because of the effort to retrieve audio information that may or may not have been properly encoded. It is also more demanding since the retrieved audio information has to be held in the working memory audio store as opposed to being readily accessible in the simultaneous presentation. Overall, theoretically, RCs can occur in a successive paradigm; however, demands are markedly higher and, as a result, RCs are less effective.

The degree to which change in terms of RC effectiveness varies from a simultaneous to a successive presentation has not been empirically investigated yet. Part of this dissertation is to

provide direct metrics of RCs to verify effectiveness across multimedia CBT presentation type (i.e., simultaneous versus successive).

RC Summary

Most multimedia literature presents the RC as a process that links simultaneously presented audio and visual information. The overall effect of RCs on knowledge acquisition is beneficial as supported by the dual-coding notion that encoding a concept across modalities is superior, in terms of subsequent information retrieval, when compared to encoding with only one modality. However, in this section, I have illustrated the theoretical possibility of linking sequentially presented audio / visual information into RCs. In addition, this section used two established models of information processing (i.e., CTML and HIP). From these models, the process of RC creation occurs as a result three main processes, which are the selection, organization, and integration of information. In turn, each of these processes draws on attention resources and involves LTM.

Overall, when the selection, organization, and integration processes are supported, RC strength is high and so is the encoding of audio / visual links into LTM. Once audio / visual links are properly encoded into LTM, their retrieval should also be facilitated. This is due to the simple theoretical concept introduced earlier that material encoded with more than one modality is more likely to be retrieved when compared to encoding material with one modality alone (e.g., Paivio, 1991). Therefore, properly moderating the main working memory processes theorized to support the creation of RCs is important to maximize RC benefits on learning. However, without properly measuring RCs and learning, all these theoretical considerations remain speculative and are only indirectly supported. This concern is one of the major thrusts behind this dissertation; hence the topic of measurement is the subject of the next section.

Measuring Referential Connection Strength and Multimedia Learning

An important aspect of this dissertation is to directly assess RCs and to gauge the strength of the relationship between RCs and cognitive learning outcomes. As such, this section describes the measures adopted to evaluate both RCs and learning.

Referential Connections Assessment

Measuring cognitive processes in the multimedia CBT arena has predominantly been done indirectly by observing the impact of CBT manipulations on learning. The specific assumption is that it is possible to infer which cognitive process or processes are operating by observing learning outcome variations, as indicated by various theoretical models. However, the lack of direct evidence or influence that cognitive processes have on learning remains ubiquitous. This issue is central to this dissertation, and an attempt to directly measure a cognitive process, in this case RCs, is undertaken. The goal, as described earlier, is twofold: (a) to provide a direct measure of RCs, and (b) to assess the link between RC strength and cognitive learning outcomes.

Measuring referential connections directly. There are two possible ways in which to measure cognitive processes directly: (a) by using objective measures or (b) by using subjective measures. The measuring of cognitive processes using objective measures (e.g., physiological measures, neuroimaging techniques, eye-tracking, dual task paradigms, etc.) is often not sensitive enough, can often only indirectly assess mental mechanisms, and is often restricted to evaluate workload and attention (e.g., Schmidt-Weigand, 2005). Other ways to objectively evaluate cognitive processes may be possible; however, their use in multimedia CBT paradigms is limited; therefore, this dissertation focuses on the use of direct subjective measures to assess RCs.

Subjectively assessing referential connections. This dissertation uses the premise that RCs reflect audio / visual links to bring forth a subjective measure that evaluates the very nature of those links. Specifically, the purpose of the RC measure is to assess the strength of audio / visual connections. There are three possible manners to achieve this: (a) with an implicit association measure showing audio / visual associations that can be either correct or incorrect, (b) with a measure composed of a number of probable and improbable connections between textual and visual aid information, in which trainees are asked to rate the extent to which a connection exists between the presented text concept and visual aid, and (c) with a recognition measure, in which trainees are presented with the same text and visual aid concepts, albeit in a multiple choice format.

The first measure (i.e., implicit association) is an adaptation of the Implicit Association Test (IAT) (see Greenwald, Nosek, & Banaji, 2003, for a description of the IAT paradigm). The theoretical premise of using an implicit association paradigm to assess RCs is that accuracy should be higher for items that describe true associations between text and visual concepts when compared to wrong associations. In other words, the recognition of learned associations should be easier when verbal / visual associations are true (e.g., pairing the word “rudder” with an image of a rudder), the same way that IAT word pairs (e.g., “Plane” and “Fear”) lead to faster responses when the association reflects a true underlying attitude. In the second measure (i.e., rating-scales RC), a trainee could be exposed to the word “rudder” and to the image of either a rudder or another airplane part. At this point, the trainee would have to rate how strongly they feel the connection exists between the two presented elements. In the recognition measure, trainees evaluate the extent to which they can accurately identify concepts. In terms of RCs, this measure offers another way to gauge the strength of referential connections, since its multiple-

choice format asks learners to identify the correct combination of text concept with its corresponding visual concept. Specific details about this measure are provided in the method section of this dissertation.

Knowledge Assessment

This importance of measuring overall cognitive learning outcomes is predominantly to assess the relationship with RCs. This dissertation uses a battery of knowledge assessment measures to evaluate the extent to which learning has occurred (e.g., Cuevas et al., 2002, Fiore et al., 2003). In particular, a successful approach to measuring knowledge involves the adoption of declarative and integrative measures (see Cuevas et al., 2002, 2004; Fiore et al., 2002, 2003). The main rationale for adopting multiple learning measures is that each evaluates a different level of knowledge elaboration, ranging from low elaboration to high elaboration (e.g., Lockhart, Craik, & Jacoby, 1976). Each of these measures is described next.

Declarative measures. Declarative measures evaluate trainees' grasp of conceptual and factual knowledge. This type of measure is a step above recognition measures in terms of level of elaboration since it often involves understanding concepts roles and functions. For example, a declarative question about the airplane's rudder could ask about the role of the rudder when maneuvering a plane (e.g., the rudder is the moving part of the vertical stabilizer that allows the plane to move around the vertical axis). Even though other concepts are present in this correct answer (i.e., vertical stabilizer and vertical axis) it is not necessary to understand them conceptually to correctly answer the declarative question. In other words, a rote memorization of the presented material would yield correct answers on declarative measures. As such, these types of measures involve low level of elaboration (e.g., Fiore et al., 2003), which, in turn, may occasionally be unable to diagnose differences in learning across training manipulations.

Integrative measures. Integrative measures can tap into what is sometimes known as procedural knowledge, describing trainees' ability to relate declarative knowledge (Jonassen & Grabowski, 1993). However, in this dissertation, the term "integrative" is used to specifically address the notion that to correctly answer an integrative question, trainees need to have developed an understanding of how concepts relate to one another. In other words, these measures are called integrative since they assess the extent to which learners are able to properly integrate knowledge from a variety of interacting concepts. As such, integrative knowledge involves a higher level of elaboration when compared to recognition and declarative measures. Most importantly, integrative measures are often able to tease apart the effects multimedia manipulations have on knowledge acquisition (Cuevas et al., 2002, 2004; Fiore et al., 2002, 2003, 2004).

Factor Categorization

A number of factors have been used in past research in computer-based multimedia learning paradigms. These factors, within the theoretical framework introduced earlier, can differentially moderate RC creation. Specifically, the framework presented in the previous section helped categorize factors according to which main information processing step (i.e., selection, organization, and integration) they support, while accounting for attention resources depletion, and the role of LTM. Table 6 provides a summarized list of these factors in relation to the manner in which they specifically affect the main working memory processes, attention resources, and LTM.

Overall, Table 6 represent an attempt to isolate how each factor influences the creation of RCs by indicating how each information processing step is affected, how attention resources and LTM chunking are affected. Furthermore, many factors discussed in isolation in the literature are

in fact similar if not identical to other factors when looking at the various effects at play. Table 6 has also grouped together factors that may belong to another factor's category (e.g., cueing factor which includes color coding). Next, for the purpose of this dissertation, Table 7 cataloged these various factors into manipulated, covaried-out, or fixed variables. The next chapter specifically describes the selected manipulations along with their respective hypothesized effects on RCs and cognitive learning outcomes.

Table 6: *Factors influencing RCs within their main category in terms of their influence on the selection, organization, integration process, attention resources, and LTM*

Factor	Category	Processes, attention, and memory				
		Selection process	Organization process	Integration process	Attention resources	Long-term memory
Information units	CBDF	Unit size may have an inverse relationship with selection	Unit size may have an inverse relationship with organization	Unit size may have an inverse relationship with integration	Unit size may proportionally deplete attention resources	The larger the unit size, the harder the top-down process
Temporal contiguity	CBDF	<i>Simultaneous</i> : more modalities can negatively impact selection	<i>Simultaneous</i> : more modalities can help organization	<i>Simultaneous</i> : more modalities can help integration (e.g., dual-coding)	<i>Simultaneous</i> : more modalities can deplete attention	<i>Simultaneous</i> : helps chunking verbal and pictorial information
		<i>Successive</i> : less modalities can help selection	<i>Successive</i> : less modalities can hinder organization	<i>Successive</i> : less modalities can hinder organization (e.g., no dual-coding)	<i>Successive</i> : less modalities can have a lesser effect	<i>Successive</i> : relies on LTM to link verbal / pictorial information
Spatial contiguity	CBDF	Proximity may help selection by minimizing eye movement	Proximity may help organization by minimizing eye movement		Proximity may minimize attention depletion	
Modality principle	CBDF	<i>Parallel</i> : narration is not displayed and does not help selection	<i>Parallel</i> : narration	<i>Parallel</i> : narration and visual aids may facilitate integration	<i>Parallel</i> : narration and visual aids have a lesser effect	<i>Parallel</i> : top-down may be less effective
		<i>Sequential</i> : text is displayed and may help selection	<i>Sequential</i> : permanent text and visual aids may aid organization	<i>Sequential</i> : text and visual aids may hinder integration	<i>Sequential</i> : text and visual aids deplete more resources	<i>Sequential</i> : top-down may be more effective
Training pace	CBDF	Self-paced may help selection	Self-paced may aid organization	Self-paced may help integration	Self-paced may have a lesser impact on resources	Self-paced may help LTM chunking
Coherence principle	CBDF	Extraneous information may hinder selection	Extraneous information may hinder organization	Extraneous information may hinder integration	Extraneous information may deplete resources	Extraneous information may hinder LTM chunking

Factor	Category	Processes, attention, and memory	Factor	Category	Processes, attention, and memory	Factor
Cueing effect, and dynamic changes	CBDF	<i>Color coding:</i> Pre-attentive technique that may help selection	<i>Color coding:</i> Pre-attentive technique that may help organization	<i>Color coding:</i> Pre-attentive technique that may help integration	<i>Color coding:</i> May not negatively affect resources	<i>Color coding:</i> May facilitate Chunking
				<i>Dynamic linking:</i> Technique that may help conceptual integration		
		<i>Inter-textual hyperlinks:</i> Pre-attentive technique that may help selection	<i>Inter-textual hyperlinks:</i> Pre-attentive technique that may help organization	<i>Inter-textual hyperlinks:</i> Pre-attentive technique that may help integration	<i>Inter-textual hyperlinks:</i> May not negatively affect resources	<i>Inter-textual hyperlinks:</i> May facilitate Chunking
Domain	CBDF					Domain specific knowledge may help chunking
Personalization effect	CBDF				May help sustained attention	
Dynamic visualizations	CBDF	May interact with congruency principle to moderate selection	May interact with congruency principle to moderate organization	May interact with congruency principle to moderate integration	May interact with congruency principle to moderate resource depletion	May interact with congruency principle to moderate chunking
3D visualizations	CBDF			Technique that may help conceptual integration		
Aging	IDF					Chunking may be more effective in elderly
Background knowledge	IDF				Minimizes attention depletion	Facilitates chunking
Goal orientation	IDF				Goal orientation training may moderate attention depletion	Goal orientation training may facilitate chunking
Learning styles	IDF	May interact with modality principle to moderate selection	May interact with modality principle to moderate organization	May interact with modality principle to moderate integration	May interact with modality principle to moderate resource depletion	May moderate LTM chunking
Spatial Ability	IDF	May interact with modality principle to moderate selection	May interact with modality principle to moderate organization	May interact with modality principle to moderate integration	May interact with modality principle to moderate resource depletion	May moderate LTM chunking
Verbal ability	IDF	May interact with modality principle to moderate selection	May interact with modality principle to moderate organization	May interact with modality principle to moderate integration	May interact with modality principle to moderate resource depletion	May moderate LTM chunking

Note: CBDF (computer-based design factor), IDF (individual difference factor)

Table 7: Proposed factor categorization

Factor	Primary category	Experimental design	Hypotheses / justification
Temporal Contiguity	CBDF	<i>Manipulation:</i> Simultaneous versus successive	- Simultaneous: leads to RC creation - Successive: no RC creation occurs
Color coding	CBDF	<i>Manipulation:</i> presence or absence of color coding	- Presence: improves RC strength - Absence: does not improve RC strength
Information units	CBDF	<i>Randomize</i>	Too complex to fix units on the easy/ difficult and simple / complex dimensions
Dynamic visualizations	CBDF	<i>Randomize</i>	Dynamic visualizations interact with congruency principle
Goal orientation	IDF	<i>Randomize</i>	Goal orientation is not assessed in this dissertation
Learning styles	IDF	<i>Randomize</i>	Learning styles are not assessed in this dissertation
Modality principle	CBDF	<i>Fix</i> at text plus visual aids	Text and visual aids (successive acquisition from registry) help selection, organization, and LTM chunking; however, they deplete more resources than narration and visual aids
Spatial contiguity	CBDF	<i>Fix</i> at integrated text	Integrated text may facilitate RC creation
Inter-textual hyperlinks	CBDF	<i>Fix</i> at absence of inter-textual hyperlinks	May interact with manipulations as an extraneous source of variability
Dynamic linking	CBDF	<i>Fix</i> at absence of dynamic linking	May interact with manipulations as an extraneous source of variability
Personalization effect	CBDF	<i>Fix</i> at non-personalized text	May interact with manipulations as an extraneous source of variability
Background knowledge	IDF	<i>Fix</i> at no background knowledge of training domain	Prior knowledge facilitates integration; however, it will minimize RC manipulation effects
Training pace	CBDF	<i>Fix</i> at learner-paced	Self-paced training may aid at all levels of information processing
Congruence principle	CBDF	<i>Fix</i> at not congruent information	Creating congruent concepts' animations may be too complex for the scope of this dissertation
Domain	CBDF	<i>Fix</i> at aviation domain	N/A
Coherence principle	CBDF	<i>Fix</i> at absence of extraneous sounds, visual aids, and written or narrated text	Absence of extraneous material may aid at all levels of information processing
Aging	IDF	<i>Fix</i> at absence of elderly	This dissertation adopted a college population
3D visualizations	CBDF	<i>Fix</i> at 2D	Enacting 3D visualization models is too complex for the scope of this dissertation
Spatial Ability	IDF	<i>Covary-out</i>	Spatial ability is measured and its variance removed
Verbal ability	IDF	<i>Covary-out</i>	Verbal ability is measured and its variance removed

Note: CBDF (computer-based design factor), IDF (individual difference factor)

CHAPTER 2: AN EMPIRICAL EXAMINATION OF REFERENTIAL CONNECTIONS AND COGNITIVE LEARNING OUTCOMES VIA TEMPORAL CONTIGUITY AND COLOR CODING MANIPULATIONS

A Multimedia Framework

The goal of this dissertation was to identify how referential connections affect knowledge integration and retention. In the previous chapter, two independent variables (IVs) have been selected in terms of importance, practicality, and interest. These two IVs – temporal contiguity and color coding– vary the manner in which the multimedia CBT is presented. Furthermore, two individual differences variables have also been selected (i.e., verbal ability and spatial ability), which effects were covaried-out for the purpose of this dissertation. All other variables were either fixed at a particular level, or randomized (see Table 7).

Together, the CBT manipulations and individual differences are theorized to either hinder or support Mayer’s (1999b) SOI working memory processes (i.e., selection, organization, and integration). In turn, these working memory processes are responsible for the creation of RCs and the long term retention of such text / visual connections. The multimedia framework, specific to this experiment in terms of training manipulations and outcomes, is conceptualized below, in Figure 6. Next, each manipulated factor and respective levels are described within such framework.

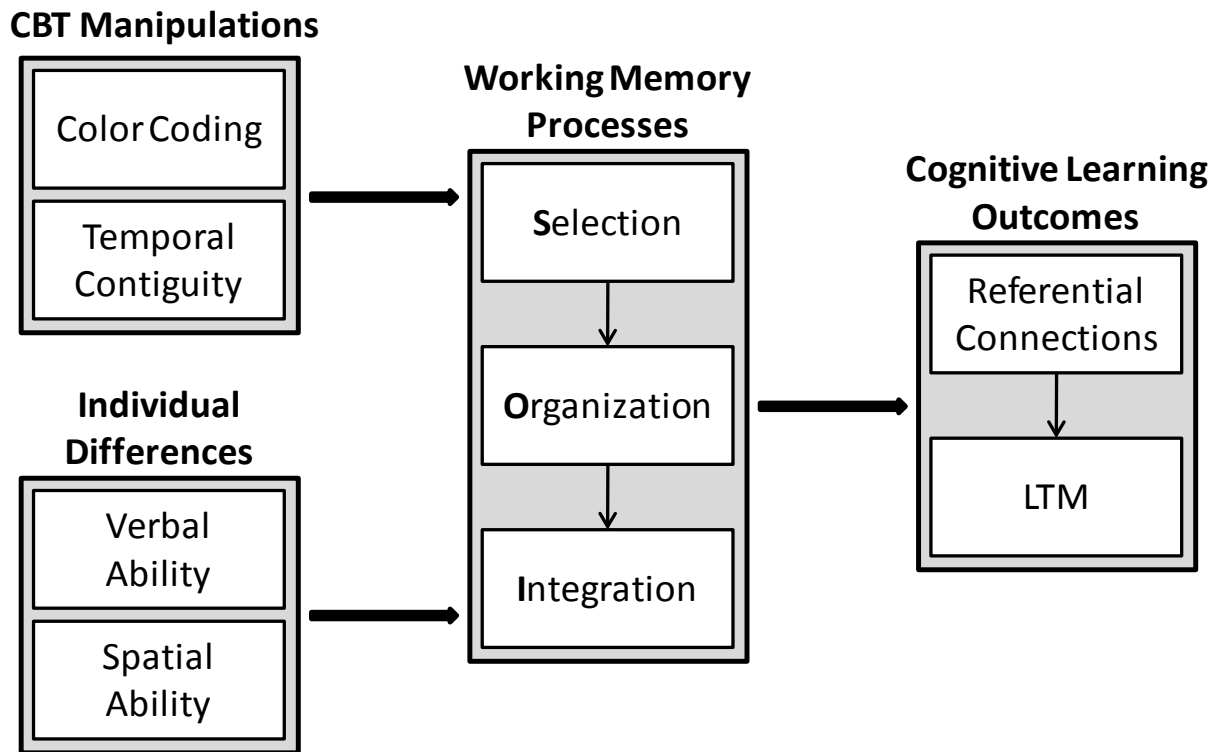


Figure 6. Multimedia framework illustrating how CBT manipulations and individual differences affect SOI working memory processes, which are responsible for RC creation and LTM retention.

Assessing the Effects of Temporal Contiguity on RCs and Learning Outcomes

Temporal Contiguity Manipulation

This factor and principle brings forth the notion that different modalities can be presented simultaneously or successively. That is, if a multimedia CBT employs both text and pictures, these can be presented either at the same time, or one at the time. A number of empirical studies directly addressed temporal contiguity by comparing successive versus simultaneous modality combinations (e.g., Kalyuga et al., 2004, Mayer & Anderson, 1991, 1992; Mayer et al., 1999;

Mayer & Sims, 1994; Moreno & Mayer, 1999, 2002; Mousavi et al., 1995; Scielzo et al., 2006). Overall, the majority of the empirical evidence underlines the importance of the temporal contiguity principle, underlining the superiority of a simultaneous presentation over a successive one in terms of cognitive learning outcomes. Next, both presentation types are described in relation to the manner in which they are presented.

Simultaneous presentation. In a simultaneous presentation, verbal (i.e., text or narration) and visual information for a given concept are presented together. There are advantages and disadvantages to this setup. Specifically, a disadvantage for the selection process is that presenting information with two modalities requires more attention resources to be allocated to identify the relevant material when compared to information presented with only one modality. That is, resources are needed for selecting both text or narration, and visual elements. However, this strain on attention resources is more pronounced when text (as opposed to narration) is employed in conjunction with visual aids. This is due to the fact that narration and visual information can be parallel processed (i.e., Paivio, 1991; Mayer, 2001; Wickens, 1997), while text and visual information, which are both visual in nature, are subject to the spatial contiguity effect (Mayer, 2001). The advantage of the simultaneous presentation format resides in the established fact that combining two modes that can be parallel processed (i.e., narration and visual aids, or text and visual aids) leads to greater cognitive learning outcomes when compared to presenting the same modalities successively. Furthermore, working memory processes support RCs with the simultaneous format. The same advantage / disadvantage scenario unfolds for the organization and integration processes. Overall, the amount of resources required to select, organize, and integrate simultaneously presented modalities mainly depends on which modalities are employed, but any combination will be superior to the successive format.

Successive presentation. A successive presentation will split the modalities explaining a particular concept over time. For example, a possible scenario could involve presenting text relevant to a given concept, and, later, presenting the visual corresponding material. The advantage of such a scenario is that less attention resources are necessary to select text or visual information. However, the theoretical benefit of dual coding, that is, RC creation, is much less pronounced if not absent, and verbal and visual information are only linked into associative connection (Paivio, 1991) via LTM. In summary, while a successive presentation of modalities requires less attention resources, between-modalities information is only linked via associative interconnections and encoding occurs only via one modality at the time. Reciprocally, while a synchronous presentation required more attention resources, between-modalities information is linked via both associative interconnections and RCs, thereby taking full advantage of dual coding.

First factor's selection criteria. The first IV, Temporal Contiguity (i.e., simultaneous versus successive), was primarily selected to isolate the extent to which RCs affect learning. Theoretically, strong RCs occur when modalities are presented simultaneously (e.g., creating a link between a text concept and its visual counterpart) (e.g., Mayer, 2001; Paivio, 1991). Therefore, it is possible to, (a) obtain an indication of how strong (simultaneous) or weak (successive) RCs can get, and (b) observe the strength of the relationship between RCs and cognitive learning outcomes. Given this, specific hypothesis are stated next.

Temporal Contiguity Hypotheses

Hypothesis 1 – RC strength. RCs are theoretically best formed when modalities are presented simultaneously to capitalize on parallel processing. Therefore, I hypothesize a main effect for temporal contiguity. Specifically, trainees in the simultaneous condition are

hypothesized to develop significantly stronger RCs when compared to trainees in the successive condition.

Hypothesis 2 – cognitive learning outcomes. The temporal contiguity principle was first developed when assessing learning performance on cognitive learning outcome measures (e.g., declarative, integrative). Therefore, I hypothesize a main effect for temporal contiguity. Specifically, trainees in the simultaneous condition are hypothesized to perform significantly better on integrative knowledge measure (Hypothesis 2A), as well as declarative measures (Hypothesis 2B), when compared to trainees in the successive condition.

Assessing the Effects of Color Coding on RCs and Learning Outcomes

Color Coding Manipulations

Color coding is better known as a pre-attentive technique (e.g., Treisman & Kanwisher, 1998) that draws attention to specific information; hence, it can be categorized as either attention cueing (e.g., Tabbers et al., 2004) or as an SLH technique (e.g., Seufert & Brunken, 2004, 2006). Overall, color coding can be seen as a technique that provides information without depleting attention resources, as indicated by subjective workload (e.g., Kaluyga et al., 1999). However, the traditional view of color coding is limiting within the multimedia information processing framework presented in this dissertation. Specifically, the use of color coding in a multimedia CBT can bring forth two new elements other than simply drawing attention to a particular concept. In particular, color coding can help distinguish among color coded information, and it can also and most importantly facilitate the information pairing between color-coded text and its identically color-coded visual counterpart. All three color coding elements can theoretically support RCs, with the former element (i.e., information pairing) being most relevant to this

dissertation since it offers the distinct potential to pair information between the audio and visual working memory systems. These color coding effects are further described next.

Color coding effects. The attention-getting element of color coding resides in its highlighting function (e.g. Tabbers et al., 2004). At this stage it does not matter what color is used, as long as the color is salient enough to highlight a given concept or informative material. In fact, the highlighting of information can be done via other traditional pre-attentive methods (e.g., italicizing, underlining, etc.) that do not typically involve color. Overall, this step can support the selection process, which is the first process within the presented multimedia information framework. Next, the distinguishing element of color coding resides in the use of different colors to highlight different concepts. That is, if concept A is highlighted with one color and concept B is highlighted with another color, then the trainee can distinguish between the two concepts. Therefore, this element of color coding can support the organization process, the second process of multimedia information processing. Finally, the information pairing element of color coding is present when the same color is used to highlight a concept that is represented both textually and graphically. This characteristic of color coding can directly support the creation of RCs and can be associated with the integration process, which is the third and last working memory process before the information is encoded into LTM.

When manipulating color coding, it is, therefore, not only important to verify how presence or absence of color coding affect RC creation and the learning process, but it is theoretically crucial to identify how the pairing function of color coding supports RC creation above and beyond its pre-attentive and distinguishing characteristics. In other words, it is the pairing effect of color coding that should be most supportive of RC creation since it directly supports the integration process in which the related verbal and visual information is encoded

into LTM. Therefore, this dissertation will investigate the effects of color coding on RC creation at three levels: Absence of color coding, color coding without pairing, and color coding with pairing. Each of these levels is described next.

Absence of color coding. The absence of color coding of any kind removes all forms of pre-attentive help a trainee may get when exposed to a multimedia CBT. This color coding level is important since it provides baseline performance to which the other color coding levels can be compared to.

Color coding without pairing. Implementing color coding without pairing means that the color coded information can be recognized and distinguishable pre-attentively; however, corresponding text and visual aids cannot be coded with the same color to avoid pairing. Practically, this means that more than one concept has to be presented at once, differentially color coding corresponding text and visual aids concepts. For example, if the concept of the ‘rudder’ and the concept of the ‘vertical stabilizer’ are presented, and each concept is represented with text and visual aids, then not only the ‘rudder’ and the ‘vertical stabilizer’ have to be coded with a different color, but the corresponding text and visual aids within a concept (i.e., the text ‘rudder’ and the image of the ruder) also have to be coded with a different color. As such, discrimination between concepts is preserved without enabling text and visual aid concept pairing. This level of color coding is important because it allows comparisons between baseline RC performance and RC performance supported at the selection and organization stage of multimedia information processing. However, the most important comparison in terms of theoretical implications occurs when taking into consideration the next level of color coding, described next.

Color coding with pairing. This level of color coding differs from the previous one (i.e., no pairing) in that each color coded concept uses the same color for corresponding text and visual aids. In other words, while different concepts are coded with different colors, the corresponding text and visual aids for any given concept are identically color coded. For example, the concept of the ‘rudder’ and the concept of the ‘vertical stabilizer’ will be color coded differently; however, the text ‘rudder’ and the image of the rudder, as well as the text ‘vertical stabilizer’ and the image of the vertical stabilizer will be identically color coded. As a result, the pairing characteristic of color coding arises and allows for pre-attentive associations between corresponding text and visual aids. Again, theoretically, it is the pairing characteristic of color coding that is thought to directly support RC creation. Empirically, this notion is supported by finding that color coding with pairing improves learning (e.g., Kalyuga et al., 1999). As such, to gauge the extent to which color coding affect RCs, it is necessary to compare performance from the color coding with no pairing condition with the color coding with pairing condition.

Second factor’s selection criteria. Besides the theoretical significance, discussed above, of using color coding as a pre-attentive technique supporting RCs, color coding was also chosen because it is one of the main documented techniques that consistently shows effects on cognitive learning outcomes (e.g., Kalyuga et al., 1999; Kozma, 2003; Tabbers et al., 2004). Therefore, it is of particular relevance to assess the extent to which RCs support the overall learning process. Specifically, RCs are purported by the multimedia literature to be one of the key mechanisms responsible for effective learning (e.g., Mayer & Anderson, 1991, 1992). As a result, comparing RC strength with learning performance can provide a clear indication of this alleged link. Specific hypotheses are brought forth next.

Color Coding Hypotheses

Hypothesis 3 – RC strength. Color coding is a pre-attentive technique that theoretically supports the three main working memory processes (i.e., selection, organization, and integration). Furthermore, integration is the process thought to most directly affect RCs. Therefore, I hypothesize a main effect for color coding. Specifically, trainees in the paired color-coding condition are hypothesized to develop significantly stronger RCs when compared to trainees in the no-pairing color-coding condition (Hypothesis 3A) and the no color-coding condition (Hypothesis 3B).

Hypothesis 4 – cognitive learning outcomes. Some empirical evidence suggests that color coding can support cognitive learning outcomes (Kalyuga et al., 1999; Tabbers et al., 2004). Theoretically, color coding, by reinforcing RCs, would also carry over the positive effect on learning. Therefore, I hypothesize a main effect of color coding. Specifically, trainees in the paired color-coding condition are hypothesized to perform significantly better than trainees in the no-color conditions on the integrative learning measures (Hypothesis 4A) as well as on declarative measures (Hypothesis 4B).

Assessing the Interaction of Temporal Contiguity by Color Coding on RCs and Learning Outcomes

Hypothesis 5 – RC Strength

I hypothesize a significant interaction between temporal contiguity and color coding on the RC measure. Specifically, trainees in the simultaneous and paired color-coding condition should develop significantly stronger RCs when compared to trainees in the simultaneous and

no-pairing color-coding condition (Hypothesis 5A), as well as the simultaneous and no color-coding condition (Hypothesis 5B).

Hypothesis 6 – Learning Outcomes

Because cognitive learning outcome measures can be sensitive enough to the manipulations in this dissertation, I hypothesize a significant interaction between temporal contiguity and color coding only on the declarative and integrative measure. Specifically, trainees in the simultaneous and paired color-coding condition should perform significantly better than trainees in the simultaneous and no-pairing color-coding condition (Hypothesis 6A), as well as the simultaneous and no color-coding condition (Hypothesis 6B).

Assessing the Relationship between Manipulated Factors, RCs, and Learning Outcomes

Another important aspect of this dissertation was to verify the extent to which RCs correlate with cognitive learning outcomes. Furthermore, this dissertation manipulated temporal contiguity and color coding which are thought to differentially affect RCs, as hypothesized above. As a result, a moderated mediation was examined to assess whether RCs mediated the relationship between the interaction of temporal contiguity and color coding in predicting cognitive learning outcomes (see Figure 7). Baron and Kenny's (1986) procedures was used to make this determination. Theoretically, the importance of isolating RCs as mediating the relationship between CBT design and cognitive learning outcomes is essential to verifying that RCs are a crucial component of the overall learning process.

Hypothesis 7 – RC Correlation to Learning

According to the multimedia framework presented in this dissertation, the strongest RCs should occur when trainees are presented with simultaneous and paired color coded modalities.

Therefore, I hypothesize a significant correlation between RCs and learning for the declarative (Hypothesis 7A) and integrative (Hypothesis 7B) knowledge measures.

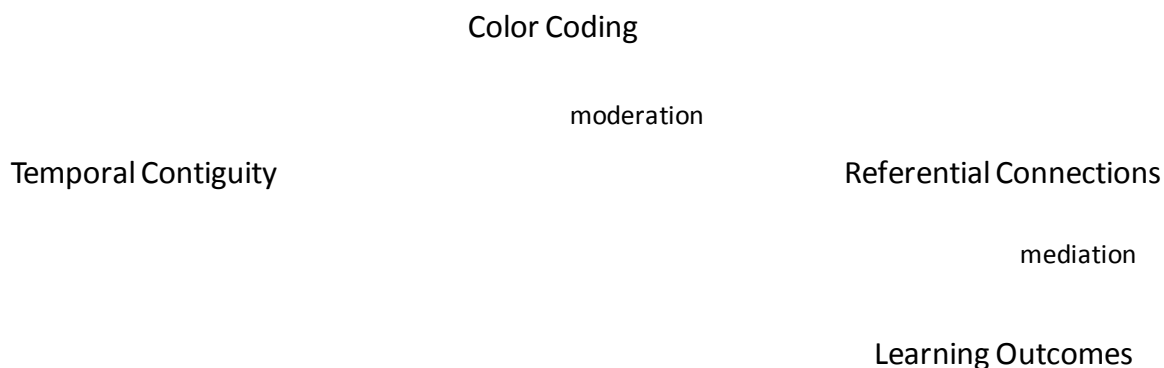


Figure 7. Representation of the moderated mediation

Hypothesis 8 – RC Mediating Learning

I hypothesize that the relationship of the interaction between temporal contiguity and color coding in predicting cognitive learning outcomes will be mediated by RCs.

Covarying-Out Verbal and Spatial Ability

Aptitude treatment interaction (ATI) in relation to multimedia CBT is documented to be particularly prominent for visual (e.g., Chun & Plass, 1997; Mayer, 2001; Scielzo et al., 2006) and verbal skills (e.g., Cuevas et al., 2002; Chun & Plass, 1997; Mayer, 2001) in terms of how it can differentially affect cognitive learning outcomes. For the purpose of this dissertation, verbal and visual skills were covaried-out to ensure that those skills would not influence cognitive learning outcomes. Finally, goal-orientation and learning styles, albeit important, were not measured since there was not enough literature supporting what specific effects are at play when learning information from a multimedia CBT.

Fixed Variables

All other variables were fixed at a particular level, as defined by Table 7. Specifically, each variable that was not manipulated, randomized, or covaried-out was fixed at the level that is more susceptible to positively affect RCs.

CHAPTER 3: METHOD

Participants

A power analysis was conducted using G*Power 3 (Faul, Erdfelder, Lang & Buchner, 2007) to assess the number of required participants according to a specified effect size and overall power (Figure 8).

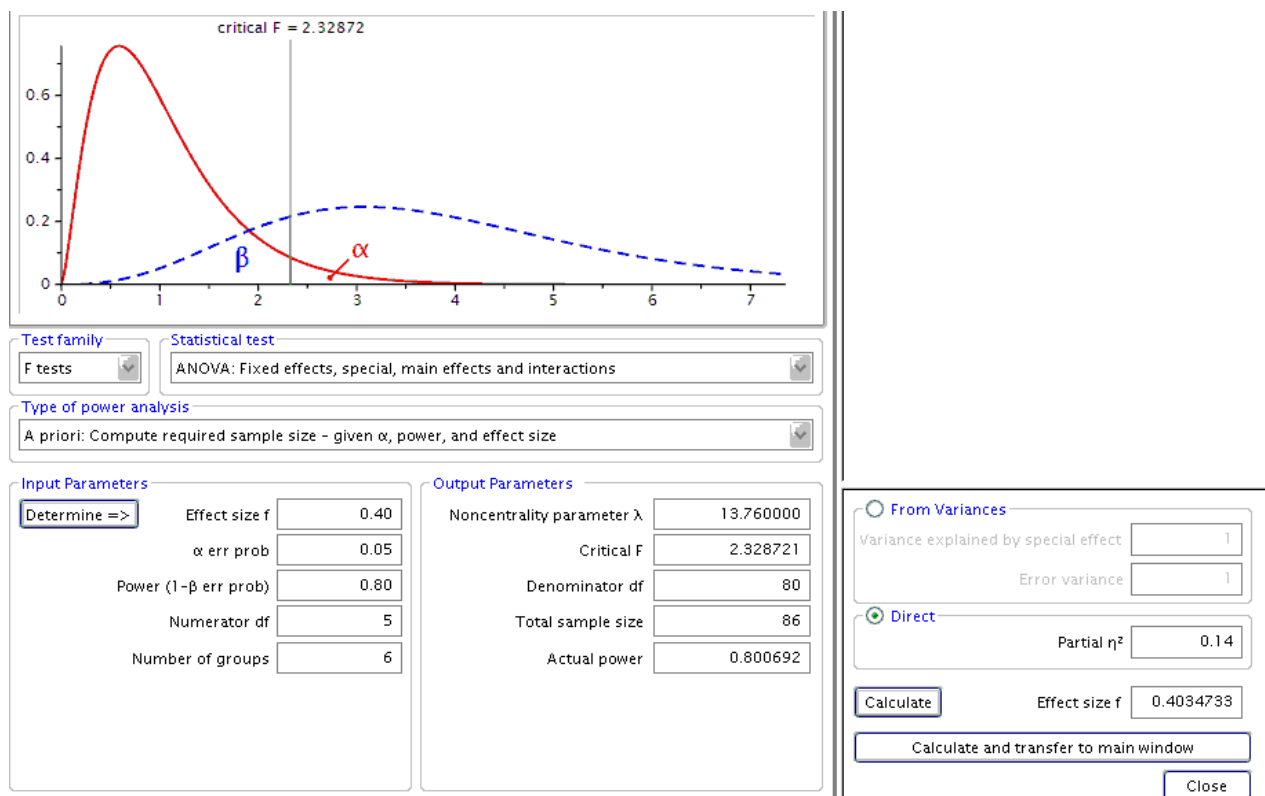


Figure 8. Screenshot of the power analysis tool G*Power 3, illustrating the parameters used to calculate the sample size.

A power level of .80 was adopted, which is an acceptable compromise between high and low power (Cohen, 1977). The G*Power 3 tool provides the option to calculate the effect size based on partial η^2 . Overall, the partial η^2 obtained from previous studies in multimedia learning have been averaged and used in G*Power 3 (Figure 8), with an obtained values of $f^2 = .40$, which

is in accordance with Faul et al. (2007) guidelines for a large effect size. A resulting total sample size of 86 participants was approximately needed, for a total of 15 participants per cell when rounding to the nearest higher integer, which brings the effective sample size suggested for this dissertation to 90. The two exclusion criteria for utilizing participants' data in this experiment were (a) prior flight knowledge and (b) suffering from any form of dyschromatopsia (i.e., color blindness).

An initial total of 107 human subjects participated in this experiment. More participants than what the power analysis required were run due to expected outliers and participants meeting the two exclusion criteria (i.e., flight knowledge and dyschromatopsia). Specifically, three participants were assessed as having a significant amount of knowledge in the domain of airplane surface parts, axes of flight, and main instruments; thus were dropped from the sample. Furthermore, six participants were diagnosed as having moderate to severe dyschromatopsia and were also dropped from the sample. Moreover, one statistical outlier (i.e., performance scores consistently three standard deviations below the mean) emerged, and after closely looking at the data for that particular participant, clear random answering patterns emerged. In addition, looking at the experimenter's log, that particular participant seemed particularly unmotivated and finished all tasks in a very limited time. Thus, that participant was also dropped from the sample. Finally, one participant did not follow the instructions for the verbal test. Since the verbal test is used as a covariate in all analyses, this data point is also dropped from the sample. A final total of 96 participants were used for all subsequent analyses, with 54 females ($M_{age} = 21.15$, $SD_{age} = 5.19$) and 42 Males ($M_{age} = 20.44$, $SD_{age} = 3.66$).

Design

A 2 Temporal Contiguity (simultaneous or successive) X 3 Color Coding (no color-coding, no-pairing color-coding, and paired color-coding) between-subjects design was used (Table 8) with spatial and verbal aptitudes used as covariates. General linear model multivariate and univariate analyses of covariance were used for statistical tests on the RC measures and on the knowledge acquisition measures. To test that the training manipulations moderated RCs, which in turn mediated cognitive learning outcomes, the Baron and Kenny hierarchical multiple regression approach was used.

Table 8: *Design matrix describing cell content for the interaction of the two IVs*

		Color Coding		
		No Color-Coding	Color-Coding with No Pairing	Color-Coding with Paring
Temporal Contiguity	Simultaneous	Text and pictures together, with no color-coding	Text and pictures together, with non-paired color-coding	Text and pictures together, with paired color-coding
	Successive	Text first then pictures, with no color-coding	Text first then pictures, with non-paired color-coding	Text first then pictures, with paired color-coding

Materials

Computer-Based Training

The training domain adopted in this dissertation was in relation to aviation, and in particular to the training of flight principles (e.g., plane’s parts, aerodynamics, instrumentation, etc.), and was based upon an elaboration of an earlier multimedia CBT testbed developed by the Team Performance Laboratory (TPL) (see Cuevas et al., 2002, Fiore et al., 2003; Scielzo et al., 2006; Scielzo, Fiore, Cuevas, & Klein, 2003). Specifically, the training environment this experiment was based upon was training naïve participants on the principles of flight. Material for the multimedia CBT was adapted from the Jeppesen Sanderson Private Pilot Manual (1996)

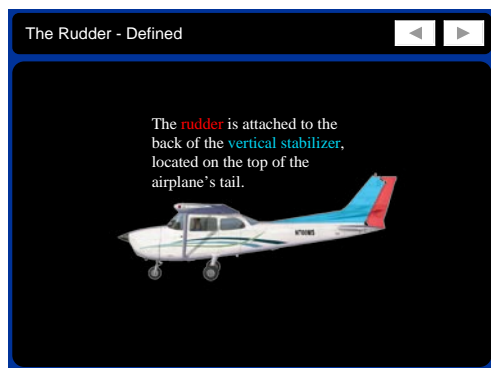
and the Jeppesen Sanderson Private Pilot Maneuvers Manual (1996), both standard training products for the instruction of pilots in the private and public sector. The multimedia CBT was divided into two modules (Airplane Parts/Flight Movements, and Flight Instruments). Each module contained a number of concepts which could be easily manipulated to fit the experimental design of this dissertation.

Trainees navigated the CBT by clicking on hyperlinked text and action buttons. The CBT was created using Microsoft® PowerPoint and saved as a 'PowerPoint Show' file in order to be used within Empirisoft® MediaLab (see relative section in apparatus). Even though the CBT was self-paced, programmed macros were implemented to ensure that (a) trainees received visual feedback in the form of a checkmark after visiting a particular concept, and (b) trainees visited all concept of a module before being allowed to continue. These macros (see Appendix B for a listing of the Visual Basic code used in the macro) were necessary to ensure that trainees visited all concepts in the CBT. All airplane pictures, including parts and instrumentation were captured from Microsoft® Flight Simulator X®, and color coding was added using Adobe® Photoshop CS2® post processing software. The two modules (i.e., airplane parts with flight movements, and flight instruments), were designed to reflect the two manipulations in this experiment (i.e., temporal contiguity and color coding) (See Appendix C for a complete version of all six CBTs). Next, a specific look at the CBT design is provided, explaining (a) the instructional theory used in the development of the CBT, (b) the manner in which temporal contiguity was implemented, (c) how color coding was developed, and (d) how concepts were distributed in each module.

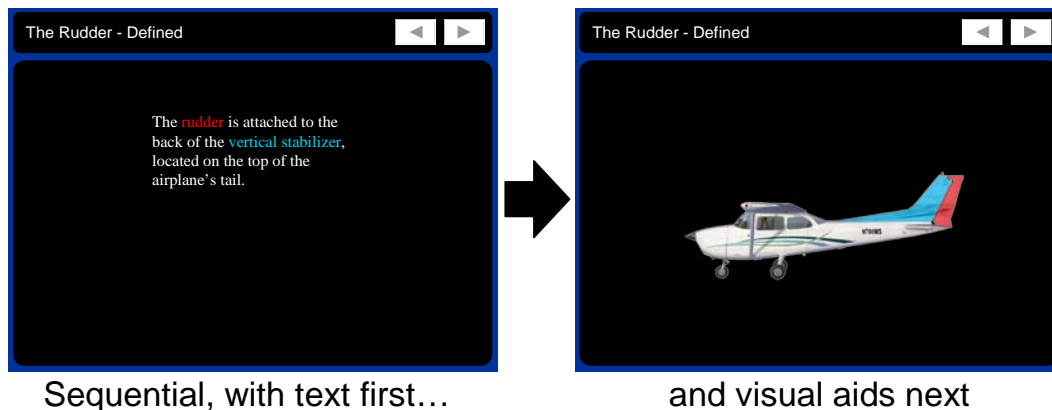
Instructional theory and CBT development. The instructional theory used to develop those modules was based on Mayer's (1999b) *constructivist learning*. Specifically, this pedagogical methodology is based on supporting SOI working-memory processes (i.e., selection,

organization, and integration). In this dissertation, the SOI processes thought to influence RCs were differentially supported via the two experimental manipulations (i.e., temporal contiguity, and color coding); thereby inducing different hypothesized cognitive learning outcomes (see previous hypotheses sections for more details). As a result, six versions of the CBT were developed, reflecting changes in temporal contiguity and color coding. Next, a specific look at each CBT version is given.

Temporal contiguity in the CBT. Temporal contiguity has been designed so that both text and visual aids remained in the same on-screen location regardless of the condition (i.e., simultaneous or successive). Figure 9 provides an example of a simultaneous and successive presentation when paired color coding was used.



Simultaneous text and visual aids



Sequential, with text first...

and visual aids next

Figure 9. CBT slide examples illustrating the simultaneous and successive CBT conditions.

Color coding the CBT. Color coding has been added ensuring that (a) the colors used were orthogonal hues from a standard color wheel to prevent the perception of two colors being similar, and (b) that the color used were highly saturated to increase the contrast with the black background used in the CBT. Figure 10 illustrates the three levels of color coding (i.e., no color, no-pairing color, and paired color) with the example of the concept of the rudder.

The no-color condition reflects the absence of any color in the text or visual aids. In this condition, trainees have to pay close attention to the text to understand what the important concepts are, and how these text and visual concepts relate.

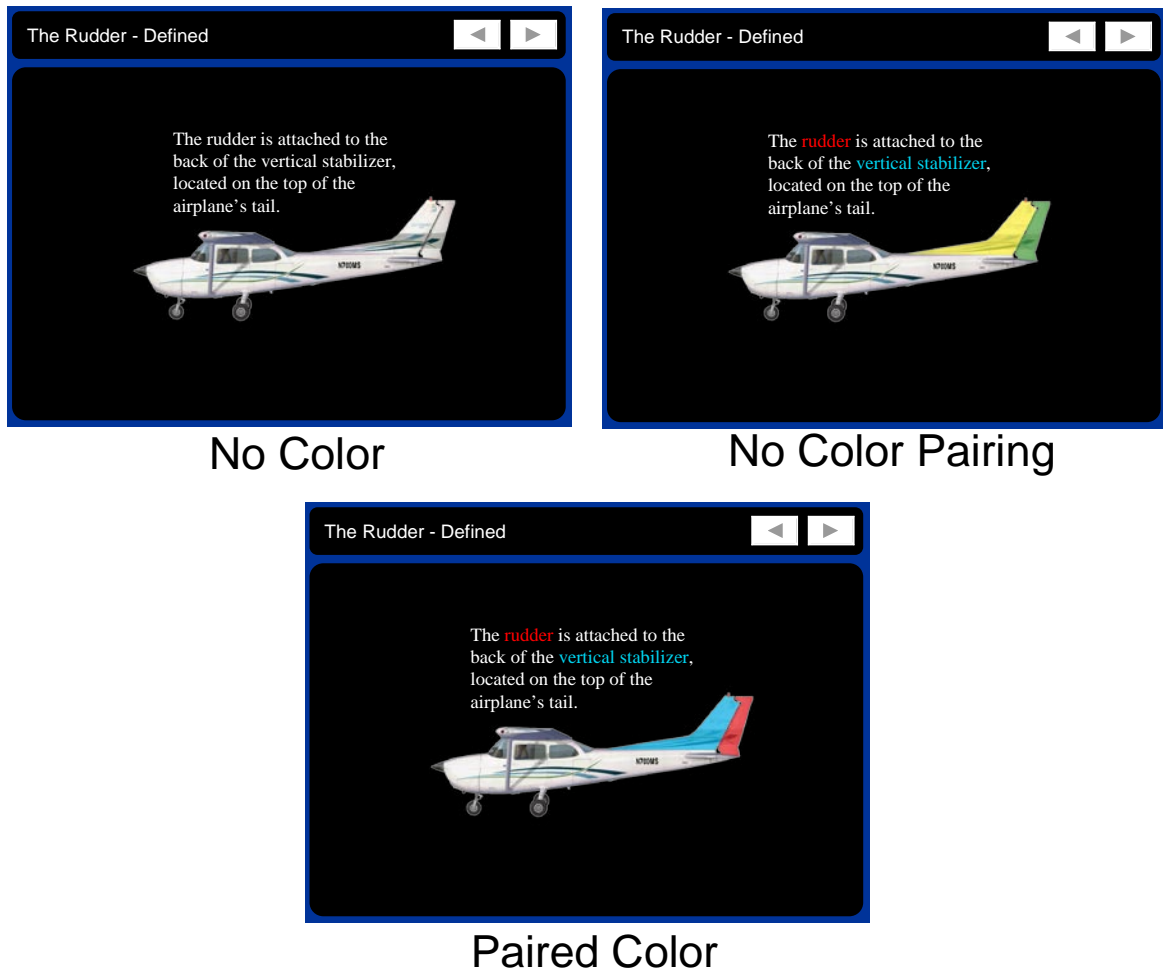


Figure 10. CBT slide examples illustrating the three color conditions.

The no-pairing color-coding condition brought the attention getting and highlighting characteristics of color coding, minus the pairing element of color coded related text and visual aids concepts. Specifically, for each color-coded text concept, the corresponding visual concepts were highlighted with a different color. In this condition, trainees' attention was guided to the important text and visual concepts; however, they still had to exert the effort of relating the correct text concept with its visual counterpart.

The paired color-coding condition differs from the no-pairing color-coding condition by matching the color coded text with its visual counterpart. Trainees in this condition not only were pre-attentively guided to important text and visual concepts, but they were also pre-attentively shown the relationship of text and visual aid concepts.

CBT modules and concepts. Airplane parts and flight instruments were introduced in Module 1. Specifically Module 1 described three airplane moving parts critical for standard flight operations. These concepts were: The ailerons, the rudder, and the elevator. Associated with these airplane moving parts, the concepts of the three axes of motion were then introduced (i.e., the longitudinal, vertical, and lateral axes) along with the movement names associated with the three axis (i.e., bank, pitch, yaw, and roll). The other concept taught in Module 1 was the center of gravity. Figure 11 presents a map of the concepts presented in Module 1.

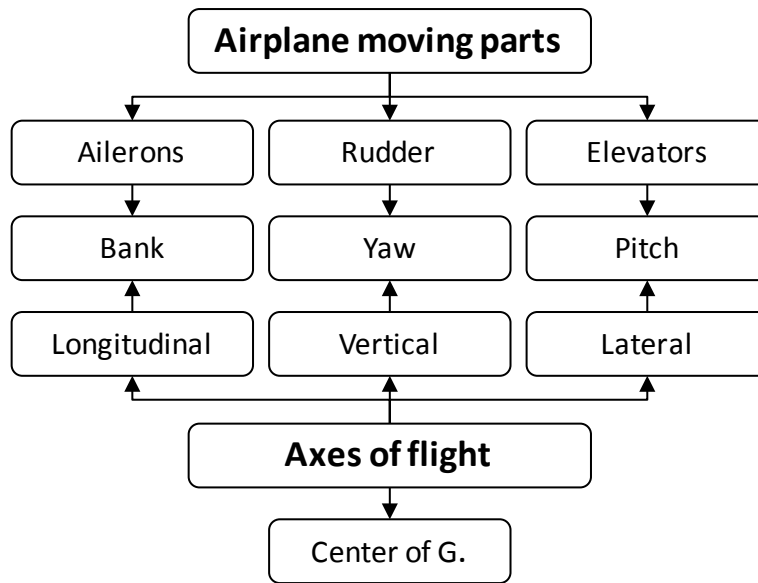


Figure 11. Module 1 map showing all the concepts taught and their relationships.

Flight instruments were introduced in Module 2. Specifically, trainees were exposed to the six primary flight instruments typically used by pilots. These instruments were divided between gyroscopic instruments (i.e., attitude indicator, turn coordinator, and heading indicator) and pitot-static instruments (i.e., airspeed indicator, altimeter, and vertical speed indicator). Figure 12 maps each of these concepts.

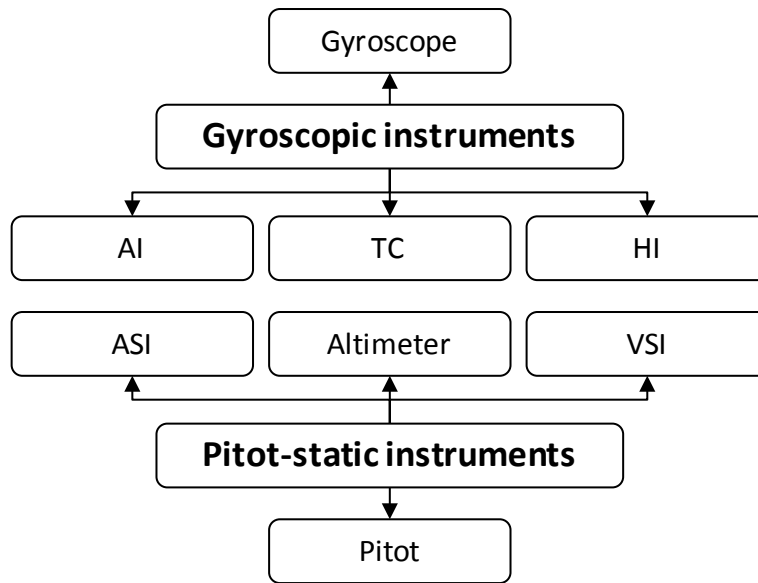


Figure 12. Module 2 map showing all the concepts taught and their relationships.

Referential Connections Assessment

This section provides a description of the development of the three RC scales used to measure the RC construct. Specific psychometrics on the scales are provided in the results section of this dissertation.

Implicit association RC test. This measure is an adaptation of the Implicit Association Test (IAT) (see Greenwald, Nosek, & Banaji, 2003, for a description of the IAT paradigm). Specifically, participants were asked to compare a text and a visual concept, and to determine whether they were the same concept or not. A total of 93 unique text-visual concept pairs were created to account for all the text and visual concepts presented in the training tutorial (These concepts, along with frequency count and category are summarized in Appendix D). Furthermore, when creating test items for the airplane surface parts (e.g., the rudder, the vertical stabilizer, etc.) the same text concept (e.g., the rudder) would be paired to the actual visual

representation; however, at four distinct levels related by distance: (a) a close-up version showing the concept and its immediate surroundings, (b) an intermediate version showing the concept with a higher level of surrounding, (c) a distant version in which the entire plane was shown, and (d) a cut-out of the concept in which only the concept was shown. This was done to assess whether RCs were stronger when a particular distance of the visual concept was shown. The other test items reflected concepts grouped in the following categories: airplane maneuvers (e.g., bank, roll), gyroscopic instruments (e.g., attitude indicator), and pitot-static instruments (e.g., vertical speed indicator).

In this test participants were asked to rate as fast as they could – while maintaining accuracy – whether the text and visual concepts were the same or different. Overall, the test was composed of a training session familiarizing participants on the procedures and test interface; then, the 93 pairs and 10 repeats were presented randomly (the repeated pairs were used to compute test-retest reliability). Empirisoft[®] DirectRT was used to program this test. Total performance was expressed in terms of accuracy and response time for the overall first RC measure – named RC1 from now on, and its four sub-categories: (a) RC1, airplane surface parts, (b) RC1, airplane maneuvers, (c) RC1, gyroscopic instruments, and (d) RC1, pitot-static instruments. Figure 13 presents an example of a true text-visual concept pair (for the complete training and test items, please refer to Appendix E).

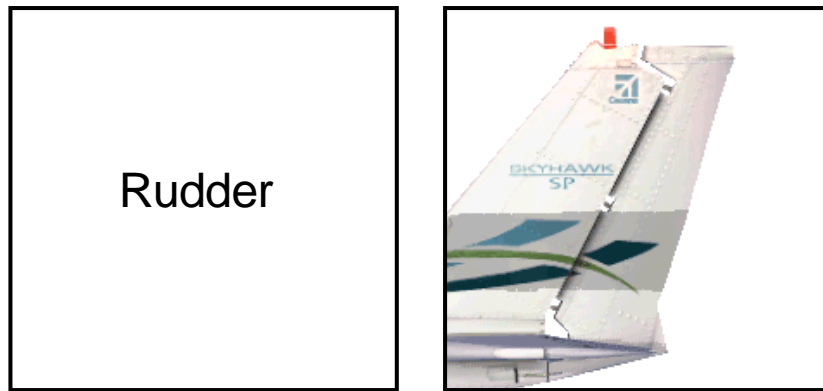


Figure 13. Example of an implicit association RC text-visual pair.

In addition to this test, another set of 12 test items were presented in a domain in which participants were not trained on. The domain chosen was from the automobile industry. Empirisoft ® DirectRT™ was also used to program this test. Specifically, each item presented a picture of a car (e.g., a Dodge Viper) with text that either identified the car correctly or incorrectly (see Figure 14 for an example item). This measure was created to test the discriminant validity of the RC1 test. Please, refer to Appendix F for the complete test.



Figure 14. Example of an implicit association RC test item from the automotive domain.

Rating-scales RC test. This second RC measure – named RC2 from now on – was composed of a number of probable and improbable connections between textual and visual aid concepts from both modules. 47 items were developed, representing all the airplane parts and

flight axes concepts presented in the tutorial in the same manner as with the previous measure (see Appendix D for the CBT concepts). Airplane instrument concepts were not used in this measure based upon the limited number of images available for instruments (i.e., only one image per instruments), whereas all other concepts (i.e., surface parts, maneuvers, and axes) had many images. Thus, since the aim of this measure was to gauge RC strength of the training concepts, the focus remained for those concepts which had several image representations (e.g., the rudder seen from different angles and distances). In other words, this measure sought to precisely gauge how multiple images of a given concept influence RC formation.

With this method, participants had to indicate – on a 5-point Likert scale – the degree to which they believed a connection exists between the text and visual concept. Overall, this test had a short training session to familiarize participants on the procedures. Next, the 47 pairs and five repeated items were presented randomly (again, the repeated pairs were used to compute test-retest reliability). Empirisoft[®] MediaLab was used to program this test, with the original stimuli created with Microsoft[®] PowerPoint. Total performance was expressed in terms of distance scores ranging from -2 (weakest relationship) to +2 (strongest relationship), with 0 indicating a neutral relationship, and response time. Another equivalent metric represented RC strength (ranging from 0 to 4) by combining the average mean strength for correct associations with reverse coded mean strength for incorrect associations. The overall RC2 measure has been computed with the 0 to 4 range, while its two sub measures (i.e., RC2 for same items, and RC2 for different items) were computed with the -2 to +2 range. Figure 15 presents an example of a test slide (for the complete training and test items, please refer to Appendix G).

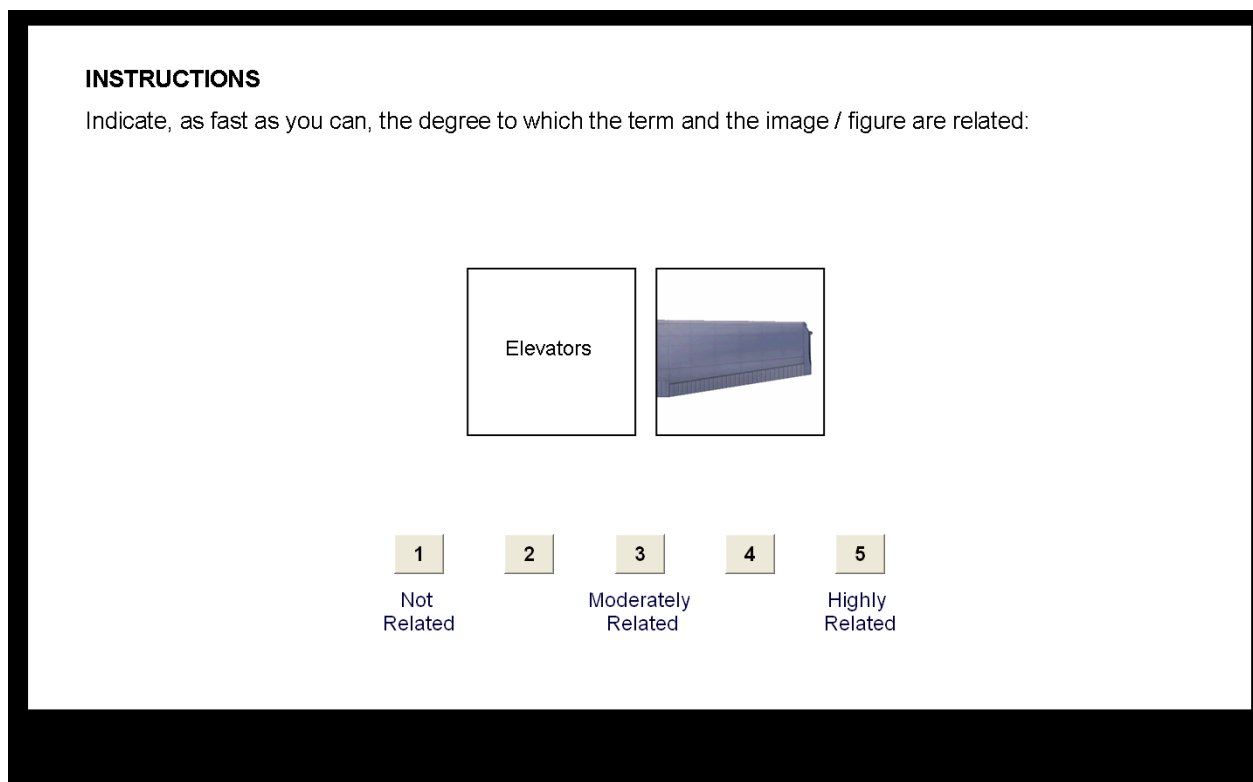


Figure 15. Example of a rating-scale RC test item.

To test convergent validity of RC2, a set of 12 test items were presented from the automobile industry domain. Empirisoft[®] MediaLab was used to program this test, with the original stimuli created with Microsoft[®] PowerPoint. Specifically, each item presented a picture of a car (e.g., a Dodge Viper) with text that either identified a characteristic of the car (e.g., economy car) correctly or incorrectly (Please, refer to Appendix H for the complete test).

Recognition measure. This third measure – named RC3 from now on – was specifically developed to further gauge RCs. Specifically, the same text concept paired with visual concept approach was used, albeit, in a multiple-choice format. That is, either a text concept was presented with four visual concept alternatives, or a visual concept was presented with four text concept alternatives. In this test, participants were asked to determine which of the four concept

alternatives was the same as the concept question (see Figure 16 for an example). Thus, not only this measure evaluated basic recognition knowledge, but it also provides an opportunity to further assess RCs.

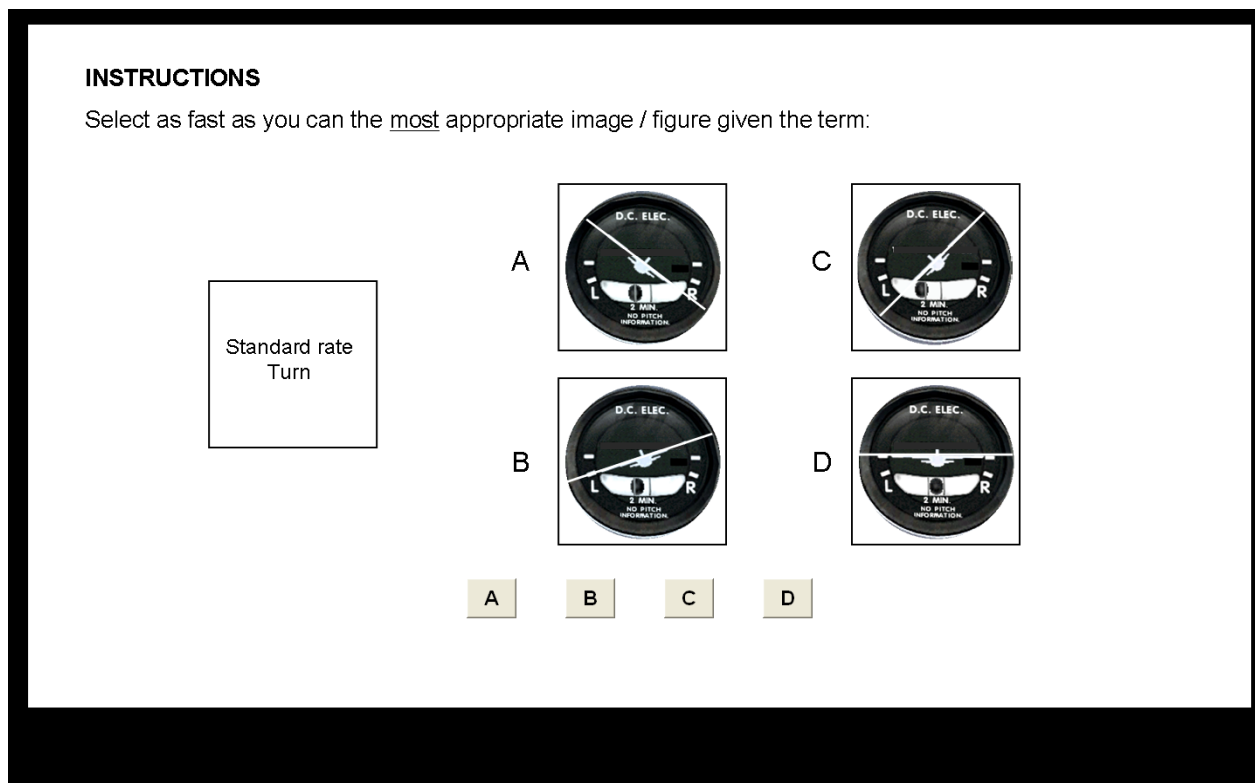


Figure 16. Example of recognition question.

This measure was first developed with Microsoft® PowerPoint in terms of content. Then each slide was exported as a bitmap image in order to be used by Empirisoft® MediaLab. A total of 40 recognition questions were created, with five of them having a visual concept as a question instead of a text concept (see Appendix I). The rationale for having a subset of visual concept questions was to determine if there were any differences in accuracy and response time between these two groups. A difference could mean that retrieval mechanisms are different when

questions are formulated with an image concept rather than a text concept. However, this notion is purely exploratory and is not part of the main investigation of this dissertation.

Participants were first exposed to a short practice session, followed by the randomized presentation of the 40 items and five repeated items (as usual, the repeated pairs were used to compute test-retest reliability). Empirisoft ® MediaLab was used to program this test, and performance was expressed in percent accuracy for the overall RC3 measure and its four subcategories: (a) RC3, airplane surface parts, (b) RC3, airplane maneuvers, (c) RC3, gyroscopic instruments, and (d) RC3, pitot-static instruments.

To test convergent validity of this measure, a set of 12 test items were presented from the automobile industry domain. Six questions had a picture of a car with four possible text choices, and six other questions had the text name of a car with four possible visual choices (i.e., car pictures) (Please, refer to Appendix J for the complete test). Only one of the four choices is accurate. Empirisoft ® MediaLab was used to program this test, with the original stimuli created with Microsoft® PowerPoint.

Knowledge Assessment

This experiment used three different knowledge assessment measures to examine cognitive learning outcomes. Similarly to the CBT, the knowledge assessment developed for this experiment was based on a previous battery of tests (see Cuevas et al., 2002; Fiore et al., 2003; Scielzo et al., 2006). First, declarative questions were presented, followed by integrative questions. All questions were presented one at the time and trainees were precluded from going back to a previously answered question. Next, a detailed description of each measure is provided.

Declarative measure. This measure's questions were adapted from the Jeppesen Sanderson Private Pilot Exercise Book (1996) to reflect the specific concepts taught in the CBT.

This measure evaluated trainees' understanding of concepts in the CBT. In other words, this measure offers a traditional way to capture the extent to which concepts are retained. Thus, in large part, this measure gauged participants' understanding of factual information about concepts in isolation, such as concepts' definitions.

This measure was developed with MediaLab, and was text based (Appendix K reports the complete measure). Specifically, 30 multiple-choice items were developed assessing factual knowledge about the concepts presented in the CBT (e.g., "Where is the rudder located?"). Overall, participants were asked to focus on accuracy, as opposed to response time. Each item had four possible choices, with only one correct answer. Each participant's accuracy was assessed in total percent correct points for the overall measure and its three sub-categories: (a) airplane surface parts, (b) gyroscopic instruments, and (c) pitot-static instruments. It is important to note that there was not 'airplane maneuvers' sub-categories because concepts related to that category were indirectly assessed by questions in the other three sub-categories. Overall, this measure obtained a reliability estimate of $\alpha = .77$, using Cronbach's *alpha*.

Integrative measure. This measure presented questions to the trainees that combined concepts from both modules. That is, in order to answer these questions correctly, trainees needed to understand the relationship between various concepts presented in the CBT. These questions had an animated component that presented the learned concepts in a novel environment. Each animation in the integrative measure was recorded from Microsoft® Flight Simulator X® using the Fraps® video-capture software. Then, each capture was standardized using Adobe® After Effects® and exported as a compressed QuickTime® movie format. Performance for the overall integrative measure was assessed as total percent correct.

Overall, this measure was divided into two subsets. The first subset presented 15 multiple-choice questions of an animated instrument cluster. The size of the instrument cluster showed two (k=5), three (k=5), and four (k=5) animated instruments at once (see Figure 17 for an example of a 4-instrument cluster). Together these instruments depicted various aircraft maneuvers (e.g., 2-minute descending turn to the North), with an animation ranging from 10 to 30 seconds. In order to answer these questions successfully, participants needed to be able to relate various concepts from the CBT together to form a mental approximation of the airplane's status. Participants had four possible choices, and only one was correct. First, the animation was shown, and then, the question relating to that animation would appear. Participants had the option to review the animation as many times as they wished before selecting their answer; however, once an answer was selected they could not go back and change their answer. Performance for the integrative instruments sub-category was assessed as total percent correct.



Figure 17. Example of a 4-instrument cluster, which is animated in the test.

The second subset presented 10 multiple-choice questions of either an exocentric (k=5) or endocentric (k=5) view of an animated airplane performing a maneuver (see Figure 18 for an

example of an exocentric view). These questions tested participant's ability to correctly determine which airplane parts, axis, and instruments were used in a particular animation. Participants first viewed the animations (ranging from 10 to 30 seconds), then they were given a question with four possible answers. Participants were free to go back and review the animations as many times as they deemed necessary; however, once they made a selection they could not go back and change their answers. Performance for the integrative maneuvers sub-category was assessed as total percent correct. A complete inventory of the integrative measure can be found in Appendix L (still images are used to represent videos). This measure obtained an overall reliability estimate of $\alpha = .80$, using Cronbach's *alpha*.



Figure 18. Example of an exocentric view of an airplane, which is animated in the test.

Aptitude Tests

Spatial aptitude. A digitally re-mastered version of Part 6 (Spatial Visualization) of the Guilford–Zimmerman Aptitude Survey (Copyright 1953 Sheridan Supply Co.) was administered

to covary-out spatial ability (cf. Fiore et al., 2003; Hegarty, Carpenter, & Just, 1996; Sims & Mayer, 2002). The original paper-pencil based spatial visualization measure was re-mastered using Adobe® Photoshop® to (a) allow the measure to be administered via computer, and (b) provide a ‘clean’ version free of visual dust and speckles. This test was composed of 40 items. All 40 items were saved as 24-bit bitmap images, and the test was programmed via MediaLab.

This test measured the extent to which participants were able to visualize spatial location, and is predictive of pilot performance (Guilford & Zimmerman, 1981). Part 6 has an estimate of reliability of 0.94, as originally computed using the Kuder-Richardson formula 21 (Guilford & Zimmerman, 1981). The digitally re-mastered CBT version has a high internal reliability, with Cronbach’s $\alpha = .96$. Participants had 10 minutes to respond to as many items as possible (see Appendix M for a complete inventory of this measure). Each items presented a ‘clock’ image as a starting point, followed by a ‘globe’ indicating via arrows how the initial image had to be rotated. Next to the ‘globe,’ four possible choices were offered, and only one choice represented a correct answer (see Figure 19 for an example). Participants were allowed to go back and change their answers. Furthermore, participants were also allowed to skip an item if they choose so. Performance was calculated by dividing the total number of correct answers by the number of total items.

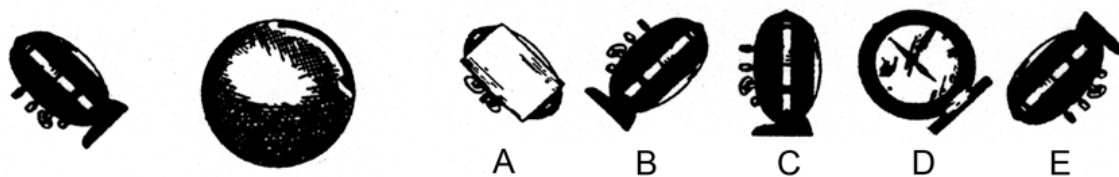


Figure 19. Example of spatial aptitude question.

Verbal comprehension. A digitally re-mastered version of Part 1 (Verbal Comprehension) of the Guilford-Zimmerman Aptitude Survey (Copyright 1953 Sheridan Supply Co.) was administered to covary-out the influence of verbal ability in comprehending the concepts in CBT. Part 1 was re-mastered using PowerPoint for content since the test is purely verbal in nature (i.e., no images). Specifically, the same 72 items from the paper-pencil version were created and saved as bitmaps in order to be used with MediaLab (see Appendix N for a complete inventory of this measure). Part 1 has an estimate of reliability of 0.91, as originally computed using Kuder-Richardson formula 21 (Guilford & Zimmerman, 1981). The digitally re-mastered CBT version also has a high internal reliability, with Cronbach's $\alpha = .90$.

Overall, participants had 10 minutes to answer to as many items as possible. As with the Part 6, participants were able to change their answers and also to skip an item. An item presented a word in bold and with all capital letter with four choices, and only one of the choices represented a true synonym (see an example in Figure 20). Performance was calculated by dividing the total number of correct answers by the number of total items; skipped and unfinished items were counted as missing items.

EARTH

- A. sugar
- B. farm
- C. sun
- D. soil
- E. horse

Figure 20. Example of verbal aptitude question.

Color Vision

Participants were screened for any forms of dyschromatopsia, such as the common red / green or blue / yellow deuteranopia, using a digitally mastered version of the Ishihara (1917) Test for Color Blindness. Overall, participants were presented with 12 items via MediaLab (see Appendix O). Each item looks like a circle filled with much smaller colored circles or ‘bubbles.’ The coloring of these bubbles is such that some items reveal a certain number when participants have red/green dyschromatopsia, and another number when participants have normal color vision (see Figure 21).

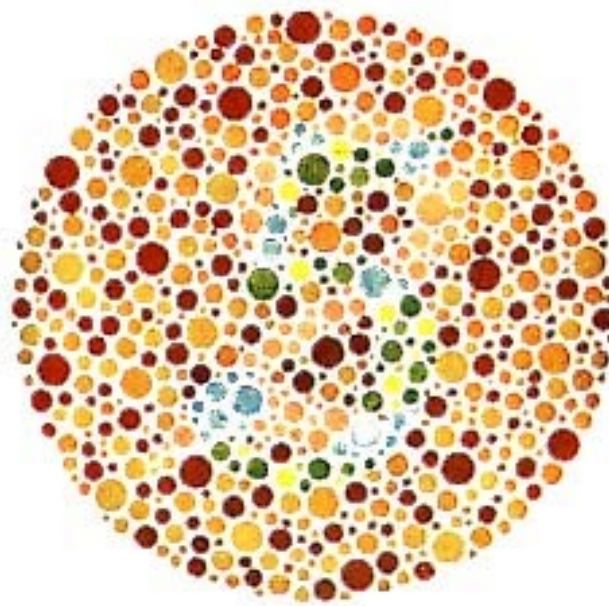


Figure 21. Example of an item from the Ishihara test for color blindness.

Apparatus

For this dissertation a number of identical DELL[®] Inspiron 9400 laptop computers were used. The main specifications for the laptops were as follows: Intel[®] Core[™] Duo central processing units, with a core speed of 1.86Mhz; Windows[®] XP operating system, with Service

Pack 2 (SP2) and Microsoft® Office 2007; 2 gigabytes of Random Access Memory; 17” WSXGA (1440 x 900 pixels) display. Each laptop was positioned 4” from the edge of a desk, and the screen’ angle was calibrated for every participant to ensure maximum perceived contrast ratio. A standard point-and-click mouse was used as an input device. Furthermore, all laptops were licensed by Empirisoft® to run both MediaLab and DirectRT content, which was the programming software used to deliver the CBT.

Procedure

Participants first read and signed an informed consent form (see Appendix P). After answering questions, if any, participants were asked to seat in front of the laptop computer and the screen was calibrated. Following calibration, the experimenter started the CBT and randomly assigned the participant to one of the six experimental conditions. At this point participants were informed to follow all instructions given on the CBT (for a full description of the experimenter’s script, please refer to Appendix Q).

First, participants were briefed about the content and various steps in the experiment (see Appendix R). Next, participants completed a biographical data sheet (soliciting demographic information such as age, gender, and prior aviation experience) (see Appendix S), followed by the Ishihara color vision test (about 10 minutes were required to complete both). Then, participants received their respective CBT about the principles of flight, proceeding through self-paced instruction, free to revisit any concept as many times as necessary. It is important to note that participants were given visual feedback in the form of a check mark for every concept that they visited. Furthermore, participants had to visit all concepts of the first module in order to

move to the second module, and, subsequently, visit all concepts of the second module in order to be allowed to terminate the tutorial, which lasted about 20 minutes on average.

After completing the training on the principles of flight, participants would then complete both spatial and verbal ability measures. These tests took about 20 minutes to complete. At this point, participants had a mandatory 5-minute break. After the break, participants were presented with the two RC measures, followed by the knowledge assessment measures (about 40 minutes were needed to complete all measures). Finally, participants were debriefed (see Appendix T). On average, the total length of the experiment was approximately 110 minutes.

CHAPTER 4: RESULTS

Since the main goal of this dissertation was to directly measure RCs, and to gauge how they mediated the impact of training on cognitive learning outcomes, I divided this chapter into two main sections. This way, I can present the results in a cohesive manner. The first section provides foundational analyses that lay the ground for all subsequent hypothesis testing. This section is composed of (a) a psychometric analysis of the RC measures used in this experiment; (b) a comprehensive table of statistics including means, standard deviations, zero-order correlations, and internal reliability; (c) a normality assessment of the measures along with other statistical parameters; and (d) a check of the random assignment procedure.

The second section presents the traditional hypothesis testing results that determined (a) what knowledge measures were significantly affected by the training manipulations; (b) whether or not related RC measures were also consistently affected by the training manipulations; and (c) to what extent these RC measures mediated the impact of training on learning; that is, on the knowledge measures.

Foundational Analyses

Psychometric Analyses of RC Scales

Since an important part of this dissertation involved the development of scales to try to measure for the first time the construct of RCs, this first sub-section provides information on the reliability and validity of these scales. Specifically, in terms of reliability, Cronbach's *alpha* is provided for internal consistency reliability, as well as an average, in percent overlap, on the

accuracy of the repeated items within the scales. In terms of validity, both discriminant and concurrent validity are investigated as well.

Reliability of RC scales. The first RC measure (i.e., an implicit association RC test) measured the construct of RC by asking participants to dichotomously answer, as quickly as possible, whether a particular pair of a text and a visual figure represented the same or different concepts. This RC1 scale contained sub-scales based on the training concept grouping, which were: Airplane moving surface parts, airplane maneuvers, airplane axes of flight, gyroscopic instruments, and pitot-static instruments.

For all sub-scales, reliability was maximized by first removing every negatively correlated item, if any, and second, by iterative deletion of further negatively or low correlating items, until the reliability could not be further improved. Table 10 provides the final number of items remaining in each scale, along with the scale's internal reliability as estimated by Cronbach's *alpha*. The other measure of reliability, test-retest, was based on 10 repeated items within the RC1 scale, which yielded an 82 percent in overlap accuracy between the repeated items. Overall, many RC1 sub-scales suffered from poor reliability; however, in light of the small number of items some sub-scales have, overall reliability may still be adequate. Furthermore, RC1 was based on dichotomous responses (i.e., same / different pairs), thus, driving reliability scores further down due to the lack in response variability.

The second RC measure (rating-scale RC test) measured the construct of RC by presenting text / visual concept pairs and requiring a response from participants about the strength of the perceived relationship between them. Respondents answered on a 5-point scale, ranging from 1 'not related' to 5 'highly related.' In this second RC scale (RC2), sub-scales were created for airplane surface parts, airplane maneuvers, and axes of flight.

The same technique as in RC1 was used to maximize reliability of the sub-scales. RC2 internal reliability values as well as number of items are provided in Table 10 as well. Overall, besides the axes of flight scales, all other RC2 scales yielded good internal reliability scores. Finally, RC2 test-retest reliability – based on five items – indicated that 84 percent of the repeated items overlapped in accuracy.

The third and last RC measure (recognition) measured the RC construct by asking participants to select the “correct” pair of text and visual representation from among four alternatives. Responses were coded as correct or incorrect. RC3 sub-scales were created for airplane surface parts, airplane maneuvers, airplane axes, gyroscopic and pitot-static instruments; thereby matching RC1 sub-scales. The only aggregate was RC3 overall, combining all sub-scales’ items. The reliability for each sub-scale was maximized as described for the RC1 measure. The overall aggregate and sub-scale number of items as well as reliability values are reported in Table 9. Overall, besides the gyroscopic instruments sub-scale, the other RC3 scales provided acceptable reliability values. In addition, RC3 test-retest reliability based on five items indicated that 75 percent of the repeated items overlapped in accuracy.

Table 9. *Internal reliability for the RC measures*

Measure	N (items)	Alpha
RC1 - Overall	54	0.659
RC1 - Surface Parts	25	0.706
RC1 - Maneuvers	9	0.531
RC1 - Axes of Flight	10	0.494
RC1 - Gyroscopic Instruments	6	0.463
RC1 - Pitot-Static Instruments	4	0.211
RC2 - Overall	35	0.880
RC2 - Surface Parts	31	0.879
RC2 - Axes of Flight	4	0.231
RC3 - Overall	21	0.755
RC3 - Surface Parts	7	0.670
RC3 - Maneuvers	5	0.520
RC3 - Axes of Flight	4	0.565
RC3 - Gyroscopic Instruments	2	0.257
RC3 - Pitot-Static Instruments	3	0.552

Discriminant and convergent validity. Discriminant validity for the RC measures (i.e., measures that should not be strongly related, indeed are not) was studied by correlating each RC overall measure with the corresponding RC scale tapping the automotive domain (see the method section for a description of these scales). Convergent validity (i.e., measures that should be strongly related, indeed are) was studied by correlating each RC overall measure with each other. Table 10 provides the correlation values as well as the significance level for both discriminant and convergent validity. Overall, discriminant validity was verified only for RC2, whereas the other two scales significantly related with their corresponding automotive domain scale. However, the significance level of the discriminant validity values was much weaker when compared to the significance level of the convergent validity values. That is, it can be argued that all RC scales did show overall discriminant and convergent validity.

Table 10. *Discriminant and convergent validity for the three RC scales*

Scale	Discriminant Validity		Convergent validity	
	<i>r</i> *	<i>p</i>	<i>r</i> *	<i>p</i>
RC1 – implicit association	.298	.005	.635	<.001
RC2 – rating-scale	-.025	.813	.572	<.001
RC3 – recognition	.268	.009	.607	<.001

* Note: all correlations reported represent the average correlation of one measure with the other two measures

In sum, all RC measures were overall reliable and valid. Thus, these measures are effectively capturing RC variability. As a result, I believe that they can be used to assess how RCs mediate learning from CBTs.

Matrix for the study variables

Table 11 presents a comprehensive table of means, standard deviations, intercorrelations, and reliability values for all the study variables.

Table 11. Measures means, standard deviations, zero-order correlations, and reliability

Variable	M	SD	1	2	3	4	5
Training Variables							
1. Temporal Contiguity (0 = sequential, 1 = simultaneous)	0.51	0.50	*				
2. Color Coding (0 = no color, 1 = color)	0.67	0.47	.01	*			
Referential Connection Measures							
3. RC1 - Surface Parts	0.56	0.15	.27	-.05	(.71)		
4. RC1 - Maneuvers	0.63	0.21	-.05	-.13	-.10	(.53)	
5. RC1 - Axes of Flight	0.73	0.18	-.13	-.04	.00	.13	(.49)
6. RC1 - Gyroscopic Instruments	0.79	0.20	-.07	.19	.08	.28	.27
7. RC1 - Pitot-Static Instruments	0.67	0.23	.09	.13	.10	.27	.22
8. RC1 - Overall	0.64	0.10	.13	-.03	.71	.42	.48
9. RC2 - Surface Parts	0.68	0.12	.05	-.02	.35	.00	.14
10. RC2 - Axes of Flight	0.92	0.11	-.03	.09	-.06	-.13	.09
11. RC2 - Overall	0.71	0.11	.04	-.01	.33	-.01	.14
12. RC3 - Surface Parts	0.96	0.12	-.04	.16	.13	.01	.22
13. RC3 - Maneuvers	0.63	0.28	-.12	.04	.07	.40	.25
14. RC3 - Axes	0.71	0.30	.06	.15	.13	.14	.37
15. RC3- Gyroscopic Instruments	0.78	0.31	.18	.07	.11	.14	.07
16. RC3 - Pitot-Static Instruments	0.61	0.35	-.03	.18	.08	.35	.25
17. RC3 - Overall	0.77	0.16	-.01	.17	.15	.34	.38
18. RC - Pitot-Static Instruments Overall	0.64	0.26	.02	.18	.21	.49	.43
19. RC - Instruments Overall	0.71	0.19	.07	.20	.13	.36	.28
20. RC - Overall	0.72	0.13	.02	.14	.21	.49	.43
Knowledge Measures							
21. Declarative - Surface Parts	0.71	0.21	-.13	.11	.21	.23	.25
22. Declarative - Axes of Flight	0.68	0.26	-.13	.12	-.08	-.04	.45
23. Declarative - Gyroscopic Instruments	0.78	0.21	.09	.03	.09	.19	.37
24. Declarative - Pitot-Static Instruments	0.72	0.18	.03	.13	.09	.16	.25
25. Integrative - Instruments	0.65	0.20	.02	.07	.15	.30	.29
26. Integrative - Maneuvers	0.45	0.22	-.11	.04	.04	.38	.35
27. Instruments Knowledge	0.72	0.18	.06	.05	.13	.27	.37
Covariates							
28. Verbal Aptitude	0.60	0.16	-.15	.15	-.11	.10	.16
29. Spatial Aptitude	3.52	1.98	.07	-.04	.03	.06	.21

Note: $N = 96$, $r \geq .21$, $p < .05$; $r \geq .26$, $p < .01$ (two-tailed). Reliabilities are reported in parentheses on the diagonal.

<i>Variable</i>	<i>M</i>	<i>SD</i>	<i>6</i>	<i>7</i>	<i>8</i>	<i>9</i>	<i>10</i>
<i>Training Variables</i>							
1. Temporal Contiguity (<i>0 = sequential, 1 = simultaneous</i>)	0.51	0.50					
2. Color Coding (<i>0 = no color, 1 = color</i>)	0.67	0.47					
<i>Referential Connection Measures</i>							
3. RC1 - Surface Parts	0.56	0.15					
4. RC1 - Maneuvers	0.63	0.21					
5. RC1 - Axes of Flight	0.73	0.18					
6. RC1 - Gyroscopic Instruments	0.79	0.20	(.46)				
7. RC1 - Pitot-Static Instruments	0.67	0.23	.22	(.21)			
8. RC1 - Overall	0.64	0.10	.50	.45	(.66)		
9. RC2 - Surface Parts	0.68	0.12	.26	.30	.41	(.88)	
10. RC2 - Axes of Flight	0.92	0.11	.18	.26	.03	.36	(.57)
11. RC2 - Overall	0.71	0.11	.27	.31	.39	.99	.46
12. RC3 - Surface Parts	0.96	0.12	.26	.23	.27	.54	.31
13. RC3 - Maneuvers	0.63	0.28	.45	.28	.42	.22	.16
14. RC3 - Axes	0.71	0.30	.08	.19	.31	.25	.08
15. RC3 - Gyroscopic Instruments	0.78	0.31	.37	.19	.27	.29	.07
16. RC3 - Pitot-Static Instruments	0.61	0.35	.32	.53	.42	.28	.12
17. RC3 - Overall	0.77	0.16	.44	.43	.52	.45	.21
18. RC - Pitot-Static Instruments Overall	0.64	0.26	.61	.62	.70	.49	.25
19. RC - Instruments Overall	0.71	0.19	.62	.67	.56	.40	.21
20. RC - Overall	0.72	0.13	.61	.62	.70	.49	.25
<i>Knowledge Measures</i>							
21. Declarative - Surface Parts	0.71	0.21	.38	.33	.45	.50	.23
22. Declarative - Axes of Flight	0.68	0.26	.10	.16	.13	.24	.25
23. Declarative - Gyroscopic Instruments	0.78	0.21	.32	.37	.38	.21	.26
24. Declarative - Pitot-Static Instruments	0.72	0.18	.28	.24	.30	.28	.10
25. Integrative - Instruments	0.65	0.20	.50	.47	.50	.43	.21
26. Integrative - Maneuvers	0.45	0.22	.49	.37	.45	.25	.12
27. Instruments Knowledge	0.72	0.18	.46	.48	.50	.36	.26
<i>Covariates</i>							
28. Verbal Aptitude	0.60	0.16	.27	.17	.10	.23	.22
29. Spatial Aptitude	3.52	1.98	.20	.23	.19	.17	.20

Note: $N = 96$, $r \geq .21$, $p < .05$; $r \geq .26$, $p < .01$ (two-tailed). Reliabilities are reported in parentheses on the diagonal.

<i>Variable</i>	<i>M</i>	<i>SD</i>	<i>11</i>	<i>12</i>	<i>13</i>	<i>14</i>	<i>15</i>
<i>Training Variables</i>							
1. Temporal Contiguity (<i>0 = sequential, 1 = simultaneous</i>)	0.51	0.50					
2. Color Coding (<i>0 = no color, 1 = color</i>)	0.67	0.47					
<i>Referential Connection Measures</i>							
3. RC1 - Surface Parts	0.56	0.15					
4. RC1 - Maneuvers	0.63	0.21					
5. RC1 - Axes of Flight	0.73	0.18					
6. RC1 - Gyroscopic Instruments	0.79	0.20					
7. RC1 - Pitot-Static Instruments	0.67	0.23					
8. RC1 - Overall	0.64	0.10					
9. RC2 - Surface Parts	0.68	0.12					
10. RC2 - Axes of Flight	0.92	0.11					
11. RC2 - Overall	0.71	0.11	(.88)				
12. RC3 - Surface Parts	0.96	0.12	.55	(.67)			
13. RC3 - Maneuvers	0.63	0.28	.23	.29	(.52)		
14. RC3 - Axes	0.71	0.30	.25	.28	.30	(.57)	
15. RC3 - Gyroscopic Instruments	0.78	0.31	.28	.26	.37	.09	(.26)
16. RC3 - Pitot-Static Instruments	0.61	0.35	.28	.36	.38	.31	.28
17. RC3 - Overall	0.77	0.16	.45	.61	.77	.65	.52
18. RC - Pitot-Static Instruments Overall	0.64	0.26	.50	.50	.72	.48	.59
19. RC - Instruments Overall	0.71	0.19	.41	.41	.52	.25	.68
20. RC - Overall	0.72	0.13	.50	.50	.72	.48	.59
<i>Knowledge Measures</i>							
21. Declarative - Surface Parts	0.71	0.21	.50	.45	.49	.47	.25
22. Declarative - Axes of Flight	0.68	0.26	.26	.29	.26	.57	.00
23. Declarative - Gyroscopic Instruments	0.78	0.21	.23	.28	.50	.38	.28
24. Declarative - Pitot-Static Instruments	0.72	0.18	.28	.37	.34	.28	.29
25. Integrative - Instruments	0.65	0.20	.43	.35	.44	.36	.34
26. Integrative - Maneuvers	0.45	0.22	.25	.26	.56	.29	.29
27. Instruments Knowledge	0.72	0.18	.37	.36	.53	.42	.35
<i>Covariates</i>							
28. Verbal Aptitude	0.60	0.16	.25	.12	.44	.17	.25
29. Spatial Aptitude	3.52	1.98	.18	.06	.13	.14	.20

Note: $N = 96$, $r \geq .21$, $p < .05$; $r \geq .26$, $p < .01$ (two-tailed). Reliabilities are reported in parentheses on the diagonal.

<i>Variable</i>	<i>M</i>	<i>SD</i>	<i>16</i>	<i>17</i>	<i>18</i>	<i>19</i>	<i>20</i>
<i>Training Variables</i>							
1. Temporal Contiguity (<i>0 = sequential, 1 = simultaneous</i>)	0.51	0.50					
2. Color Coding (<i>0 = no color, 1 = color</i>)	0.67	0.47					
<i>Referential Connection Measures</i>							
3. RC1 - Surface Parts	0.56	0.15					
4. RC1 - Maneuvers	0.63	0.21					
5. RC1 - Axes of Flight	0.73	0.18					
6. RC1 - Gyroscopic Instruments	0.79	0.20					
7. RC1 - Pitot-Static Instruments	0.67	0.23					
8. RC1 - Overall	0.64	0.10					
9. RC2 - Surface Parts	0.68	0.12					
10. RC2 - Axes of Flight	0.92	0.11					
11. RC2 - Overall	0.71	0.11					
12. RC3 - Surface Parts	0.96	0.12					
13. RC3 - Maneuvers	0.63	0.28					
14. RC3 - Axes	0.71	0.30					
15. RC3 - Gyroscopic Instruments	0.78	0.31					
16. RC3 - Pitot-Static Instruments	0.61	0.35	(.55)				
17. RC3 - Overall	0.77	0.16	.71	(.76)			
18. RC - Pitot-Static Instruments Overall	0.64	0.26	.75	.92	(.66)		
19. RC - Instruments Overall	0.71	0.19	.80	.77	.85	(.64)	
20. RC - Overall	0.72	0.13	.75	.92	.79	.92	(.69)
<i>Knowledge Measures</i>							
21. Declarative - Surface Parts	0.71	0.21	.31	.61	.36	.44	.60
22. Declarative - Axes of Flight	0.68	0.26	.21	.44	.22	.17	.33
23. Declarative - Gyroscopic Instruments	0.78	0.21	.26	.54	.34	.42	.54
24. Declarative - Pitot-Static Instruments	0.72	0.18	.33	.48	.33	.41	.47
25. Integrative - Instruments	0.65	0.20	.50	.60	.56	.63	.68
26. Integrative - Maneuvers	0.45	0.22	.49	.60	.51	.58	.66
27. Instruments Knowledge	0.72	0.18	.42	.64	.51	.60	.69
<i>Covariates</i>							
28. Verbal Aptitude	0.60	0.16	.20	.38	.22	.32	.37
29. Spatial Aptitude	3.52	1.98	.17	.21	.22	.28	.28

Note: $N = 96$, $r \geq .21$, $p < .05$; $r \geq .26$, $p < .01$ (two-tailed). Reliabilities are reported in parentheses on the diagonal.

<i>Variable</i>	<i>M</i>	<i>SD</i>	<i>21</i>	<i>22</i>	<i>23</i>	<i>24</i>	<i>25</i>
<i>Training Variables</i>							
1. Temporal Contiguity (<i>0 = sequential, 1 = simultaneous</i>)	0.51	0.50					
2. Color Coding (<i>0 = no color, 1 = color</i>)	0.67	0.47					
<i>Referential Connection Measures</i>							
3. RC1 - Surface Parts	0.56	0.15					
4. RC1 - Maneuvers	0.63	0.21					
5. RC1 - Axes of Flight	0.73	0.18					
6. RC1 - Gyroscopic Instruments	0.79	0.20					
7. RC1 - Pitot-Static Instruments	0.67	0.23					
8. RC1 - Overall	0.64	0.10					
9. RC2 - Surface Parts	0.68	0.12					
10. RC2 - Axes of Flight	0.92	0.11					
11. RC2 - Overall	0.71	0.11					
12. RC3 - Surface Parts	0.96	0.12					
13. RC3 - Maneuvers	0.63	0.28					
14. RC3 - Axes	0.71	0.30					
15. RC3 - Gyroscopic Instruments	0.78	0.31					
16. RC3 - Pitot-Static Instruments	0.61	0.35					
17. RC3 - Overall	0.77	0.16					
18. RC - Pitot-Static Instruments Overall	0.64	0.26					
19. RC - Instruments Overall	0.71	0.19					
20. RC - Overall	0.72	0.13					
<i>Knowledge Measures</i>							
21. Declarative - Surface Parts	0.71	0.21	(.62)				
22. Declarative - Axes of Flight	0.68	0.26	.31	(.38)			
23. Declarative - Gyroscopic Instruments	0.78	0.21	.42	.26	(.55)		
24. Declarative - Pitot-Static Instruments	0.72	0.18	.43	.20	.43	(.39)	
25. Integrative - Instruments	0.65	0.20	.56	.25	.56	.42	(.72)
26. Integrative - Maneuvers	0.45	0.22	.48	.20	.42	.33	.61
27. Instruments Knowledge	0.72	0.18	.55	.29	.89	.48	.88
<i>Covariates</i>							
28. Verbal Aptitude	0.60	0.16	.31	.18	.43	.29	.25
29. Spatial Aptitude	3.52	1.98	.15	.16	.38	.25	.41

Note: $N = 96$, $r \geq .21$, $p < .05$; $r \geq .26$, $p < .01$ (two-tailed). Reliabilities are reported in parentheses on the diagonal.

<i>Variable</i>	<i>M</i>	<i>SD</i>	26	27	28	29
<i>Training Variables</i>						
1. Temporal Contiguity (<i>0 = sequential, 1 = simultaneous</i>)	0.51	0.50				
2. Color Coding (<i>0 = no color, 1 = color</i>)	0.67	0.47				
<i>Referential Connection Measures</i>						
3. RC1 - Surface Parts	0.56	0.15				
4. RC1 - Maneuvers	0.63	0.21				
5. RC1 - Axes of Flight	0.73	0.18				
6. RC1 - Gyroscopic Instruments	0.79	0.20				
7. RC1 - Pitot-Static Instruments	0.67	0.23				
8. RC1 - Overall	0.64	0.10				
9. RC2 - Surface Parts	0.68	0.12				
10. RC2 - Axes of Flight	0.92	0.11				
11. RC2 - Overall	0.71	0.11				
12. RC3 - Surface Parts	0.96	0.12				
13. RC3 - Maneuvers	0.63	0.28				
14. RC3 - Axes	0.71	0.30				
15. RC3 - Gyroscopic Instruments	0.78	0.31				
16. RC3 - Pitot-Static Instruments	0.61	0.35				
17. RC3 - Overall	0.77	0.16				
18. RC - Pitot-Static Instruments Overall	0.64	0.26				
19. RC - Instruments Overall	0.71	0.19				
20. RC - Overall	0.72	0.13				
<i>Knowledge Measures</i>						
21. Declarative - Surface Parts	0.71	0.21				
22. Declarative - Axes of Flight	0.68	0.26				
23. Declarative - Gyroscopic Instruments	0.78	0.21				
24. Declarative - Pitot-Static Instruments	0.72	0.18				
25. Integrative - Instruments	0.65	0.20				
26. Integrative - Maneuvers	0.45	0.22	(.61)			
27. Instruments Knowledge	0.72	0.18	.58	(.72)		
<i>Covariates</i>						
28. Verbal Aptitude	0.60	0.16	.28	.38	(.90)	
29. Spatial Aptitude	3.52	1.98	.24	.45	.39	(.96)

Note: $N = 96$, $r \geq .21$, $p < .05$; $r \geq .26$, $p < .01$ (two-tailed). Reliabilities are reported in parentheses on the diagonal.

Normality Assessment

The data, based on a total of 96 participants, was screened for normality on all overall RC aggregates, dependent measures, and covariates. Table 12 shows that no measure was significantly kurtotic; however, four measures ended up being significantly negatively skewed, indicating that, for these measures, most participants tended to perform well. In spite of this violation of parametric assumptions, and to preserve the interpretability of the measures' scales and ranges, no corrections were applied to the variables with significantly skewed distributions.

Table 12. *Normality assessment of the dependent measures in terms of skewness and kurtosis*

Measure	N	Skewness	Std. Error of Skewness	sig.*	Kurtosis	Std. Error of Kurtosis	sig.*
Declarative overall mean	96	-0.65	0.25	Y	0.04	0.49	N
Integrative overall mean	96	-0.21	0.25	N	-0.69	0.49	N
RC1 overall mean	96	0.13	0.25	N	-0.68	0.49	N
RC2 overall mean	96	-0.99	0.25	Y	0.25	0.49	N
RC3 overall mean	96	-0.71	0.25	Y	0.43	0.49	N
Verbal covariate	96	0.07	0.25	N	-0.33	0.49	N
Spatial covariate	96	-0.50	0.25	Y	-0.67	0.49	N

*Significance, as indicated by Y, is determined by dividing the absolute value of skewness and kurtosis by their respective standard error and verifying that the obtained value > 1.96.

Assessment of the Covariates

This experiment used both verbal and spatial measures as covariates to remove participants' variability on those two dimensions. Table 13 presents zero-order correlations of the two CVs with all the DVs. Overall, the CVs significantly correlated with all integrative measures, most declarative measures, and most RC measures. These results justified the inclusion of both DVs in all analyses.

Table 13. *Correlations of the verbal and spatial covariates with all the dependent measures*

Scale	Verbal measure		Spatial measure	
	<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>
RC1_SurfacePartsOverall	-0.11	0.14	0.03	0.40
RC1_ManeuversOverall	0.10	0.17	0.06	0.29
RC1_AxesOfFlightOverall	0.16	0.06	0.21	0.02*
RC1_GyroInstrumentsOverall	0.27	0.00**	0.20	0.02*
RC1_PitotInstrumentsOverall	0.17	0.05*	0.23	0.01*
RC1_Overall	0.10	0.18	0.19	0.03*
RC2_SurfacePartsOverall	0.23	0.01*	0.17	0.05*
RC2_AxesofFlightOverall	0.22	0.02*	0.20	0.02*
RC2_Overall	0.25	0.01*	0.18	0.04*
RC3_SurfacePartsOverall	0.12	0.11	0.06	0.28
RC3_ManeuversOverall	0.44	0.00**	0.13	0.10
RC3_AxesOverall	0.17	0.05*	0.14	0.09
RC3_GyroOverall	0.25	0.01*	0.20	0.03*
RC3_PitotOverall	0.20	0.02*	0.17	0.05*
RC3_Overall	0.38	0.00**	0.21	0.02*
Declarative_AirplaneParts	0.31	0.00**	0.15	0.08
Declarative_Axes	0.18	0.04*	0.16	0.06
Declarative_GyroInstruments	0.43	0.00**	0.38	0.00**
Declarative_PitotInstruments	0.29	0.00**	0.25	0.01*
Integrative_Instruments	0.25	0.01*	0.41	0.00**
Integrative_Maneuvers	0.28	0.00	0.24	0.01*

* indicates significance with $p < .05$ (one-tailed)

** indicates significance with $p < .01$ (one-tailed)

Collapsing Color Levels in the Color Condition

Preliminary analyses revealed that the paired color and non-paired color conditions did not differ significantly. To test this hypothesis, independent paired-samples t-Tests were conducted on the dependent measures listed in Table 13 between the paired color and non-paired color grouping variables. Results indicated that for virtually all dependent measures, no significant differences emerged between the paired color and the non-paired color condition. Thus, to retain participants, these two groups were collapsed into an overall color grouping variable. As a result, the new color condition only had two levels: color and no color.

Check of Random Assignment

One-way analyses of variance were conducted on the main biographical variables to determine whether or not they were equally distributed among the various grouping variables. Specifically, the independent variable was experimental condition (simultaneous and color, simultaneous and no color, sequential and color, sequential and no color). The dependent variables used were degree of color blindness (i.e., severe, moderate, none), age, gender (i.e., male or female), handedness (i.e., right-handed, left-handed, and ambidextrous), GPA, native language (i.e., English, not English), degree of prior experience, and workload. Only GPA was nearly significant, with $F(3, 92) = 3.89, p = .06$, two-tailed. Post-hoc analyses using Fisher LSD test revealed significant differences in that participants in the simultaneous, color condition ($M = 2.95, SD = 0.47$) had lower GPAs than participants in both the simultaneous, no color condition ($M = 3.36, SD = 0.33$) and the sequential, no color condition ($M = 3.24, SD = 0.38$). However, no significant correlations were found between GPA and any of the RC and knowledge measures. Thus, random assignment appeared to have been largely successful.

Training and Cognitive Learning Outcomes

Hypothesis Testing Structure

This section on cognitive learning outcomes, as well as the next section on training and RCs do not follow the hypotheses in the order that they were introduced in the Introduction; rather, the hypotheses were tested according to what this dissertation sought out to accomplish: (a) determine the knowledge measures that were significantly affected by the training manipulations, (b) assess whether or not the corresponding RC measures were also significantly affected by the training manipulations, and (c) gauge to what extent these RC measures mediated

the impact of training on learning. A complete summary of all results, including those for outcome measures not affected by training and following the hypotheses order, is provided for archival purposes in Appendix A.

Statistical Setup

Two 2 x 2 between-subjects analyses of covariance were performed on the various cognitive learning outcome measures, to assess the impact of training. Independent variables (IVs) were temporal contiguity (sequential versus simultaneous) and color coding (no color versus color), factorially combined. The DVs were: declarative knowledge of airplane surface parts; declarative knowledge of airplane axes of flight; declarative knowledge of gyroscopic instruments; declarative knowledge of pitot-static instruments; integrative knowledge of airplane instruments; and, integrative knowledge of airplane maneuvers; (see end of Table 13). Spatial and verbal aptitudes were covariates in all analyses. Analyses were performed using SPSS General Linear Model ANCOVA, and the results are reported with $\alpha = .05$, one- or two-tailed, depending on whether a specific directional hypothesis had been stated. Besides unequal cell sizes and a significantly skewed distribution for the overall declarative aggregate (i.e., average of declarative airplane parts, axes of flight, gyroscopic instruments, and pitot-static instruments), parametric assumptions of linearity, homogeneity of variance, homogeneity of regression, and reliability of the CVs were satisfactory.

Main Effects of Training on Cognitive Learning Outcomes

Contrary to Hypothesis 2A and 2B, no main effects of either temporal contiguity or color were found on any of the cognitive learning outcome measures. This lack of main effects is explained by the occurrence of significant interactions, presented next.

Interaction of Temporal Contiguity and Color Coding on Learning

Hypothesis 6B was partially supported, with some measures of knowledge revealing significant interactions. I report on the specific knowledge measures for which the training did have an effect in order to gauge the extent to which RCs affected cognitive learning outcomes.

Interaction of temporal contiguity and color coding on declarative knowledge. The declarative, gyroscopic instruments measure, showed a significant interaction of temporal contiguity by color coding, with $F(1, 90) = 4.23, p = .021$, partial $\eta^2 = .045$ (see Figure 22). Post-hoc tests using the Duncan Statistic showed a difference between participants who received simultaneous, color CBT ($M = .83, SE = .03$) when compared to participants who received the sequential, color CBT ($M = .72, SE = .03$), $p = .039$ (one-tailed). That is, as hypothesized, color would help in the simultaneous condition more so than in the sequential condition. Furthermore, Figure 30 shows a cross-over interaction, indicating that while color ($M = .83, SE = .03$) was beneficial in the simultaneous condition, it was not for the sequential condition ($M = .72, SE = .03$). Conversely, while no color was better for the sequential condition ($M = .82, SE = .04$), it was not for the simultaneous condition ($M = .76, SE = .05$).

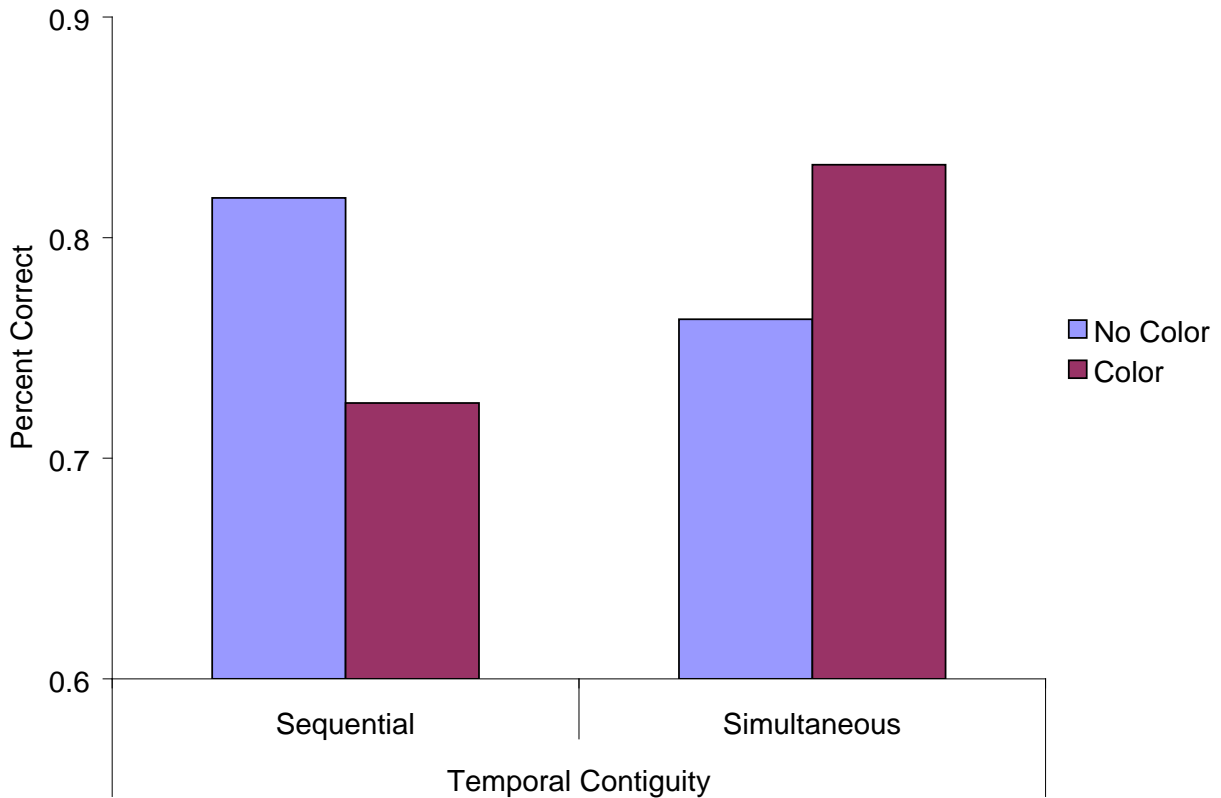


Figure 22. Temporal contiguity by color coding interaction on declarative, gyroscopic instruments measure.

Interaction of temporal contiguity and color coding on integrative knowledge. The integrative instruments measure showed a significant interaction of temporal contiguity by color coding, with $F(1, 90) = 3.10, p = .040, \text{partial } \eta^2 = .033$ (see Figure 23). Similar to the previous interaction, post-hoc tests using the Duncan Statistic showed a significant difference between participants who received simultaneous, color CBT ($M = .68, SE = .03$) when compared to participants who received the sequential, color CBT ($M = .63, SE = .03, p = .050$ (one-tailed)). That is, while color was helpful for the simultaneous condition, it actually reduced performance in the sequential condition.

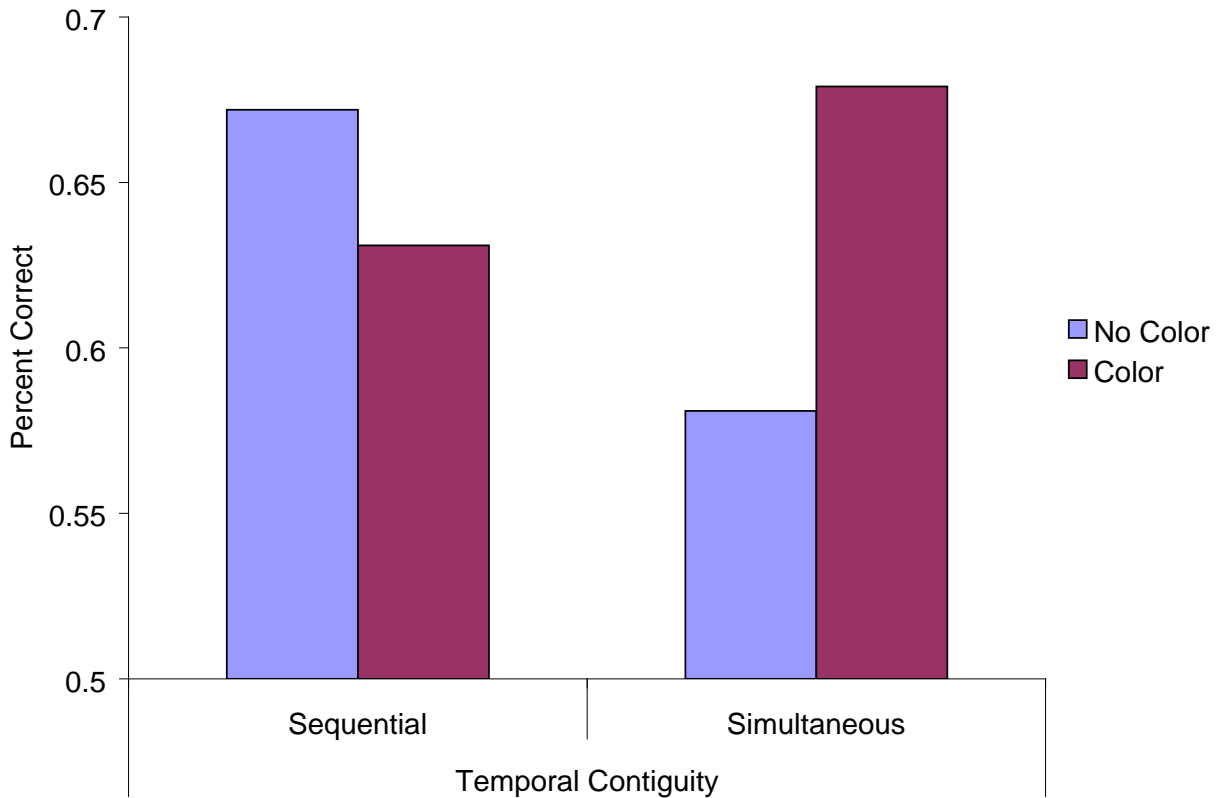


Figure 23. Temporal contiguity by color coding interaction on integrative, instrument measure.

Training Effects on a New Overall Instruments Knowledge Aggregate

A new aggregate, instruments knowledge, was created by combining the two instrument measures that yielded significant effects (i.e., declarative gyroscopic instruments, and integrative pitot-static instruments). The intent was to (a) remediate to the lack of overall instruments knowledge measure, (b) capture the variance from both measures into a measure that reflected knowledge of instruments more globally, and (c) determine if the relationship between the training manipulations and this overall instruments measure is mediated by RCs. The reliability of this new aggregate, based on two items, was high, with Cronbach’s $\alpha = 0.716$.

The instruments knowledge measure showed a significant interaction of temporal contiguity by color coding, with $F(1, 90) = 4.99, p = .014$, partial $\eta^2 = .053$ (see Figure 24). The

overall significance of the interaction came from the same differential effects reported in the previous measure. Specifically, the cross over interaction showed that while color ($M = .76$, $SE = .03$) was beneficial in the simultaneous condition, it was not for the sequential condition ($M = .68$, $SE = .03$). Conversely, the sequential no color condition ($M = .75$, $SE = .04$) yielded a higher mean than the simultaneous no color condition ($M = .67$, $SE = .04$).

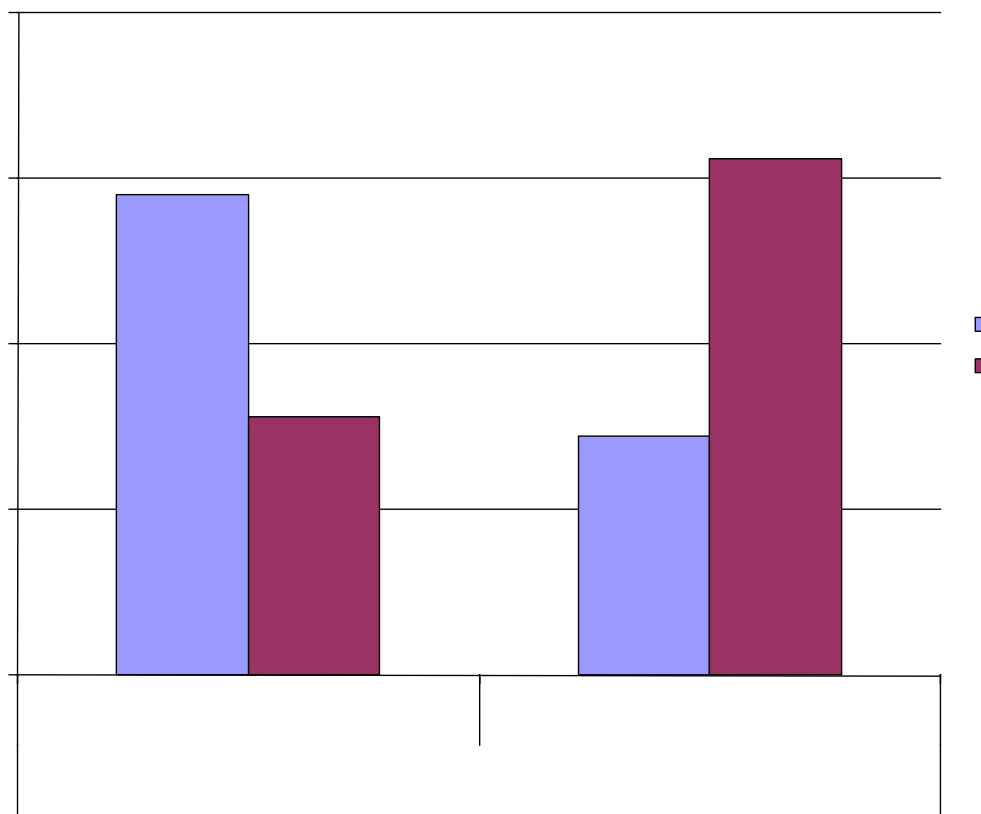


Figure 24. Temporal contiguity by color coding interaction on the instruments knowledge measure.

Training and Referential Connections

Statistical Setup

Several 2 x 2 between-subjects analyses of covariance were performed on the various RC scales that related to instruments. RC2 had no items relating to instruments; therefore, none of

the RC2 measures are present in these results. The scales of interest were RC1 gyroscopic instruments overall, RC1 gyroscopic instruments same items, RC1 gyroscopic instruments different items, RC1 pitot-static instruments overall, RC1 pitot-static instruments same items, RC1 pitot-static instruments different items, RC3 gyroscopic instruments overall, and RC3 pitot-static instruments overall. Due to the significant correlations of topic (i.e., gyroscopic instruments overall, pitot-static instruments overall) across methods (i.e., RC1 and RC3) (see Table 14), these DVs have been grouped by topic into multivariate analyses. The independent variables (IVs) consisted of temporal contiguity (sequential and simultaneous) and color coding (no color versus color), factorially combined. Spatial and verbal aptitudes were covaried-out. For these two sets of DVs, analyses were performed using SPSS General Linear Model MANCOVA, reporting Wilks' Lambda. For all other DVs, analyses were performed using SPSS General Linear Model ANCOVA. For all analyses, besides unequal cell sizes, parametric assumptions of linearity, homogeneity of variance, homogeneity of regression, and reliability of the CVs were satisfactory, unless reported otherwise.

Table 14. *Correlations of RC instruments scales*

Scale	RC1-GyroInstruments Overall		RC1-PitotInstruments Overall		RC3-GyroOverall	
	<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>
RC1-PitotInstruments Overall	.22*	.02	1.00	.		
RC3-GyroOverall	.37**	<.01	.19*	.03	1.00	.
RC3-PitotOverall	.32**	<.01	.53**	<.01	.28**	<.01

* $p < .05$ (one-tailed), ** $p < .01$ (one-tailed)

Main Effects of Training on Instrument RCs

Temporal contiguity main effects. Hypothesis 1 was supported with the RC measures on gyroscopic instruments (RC1 and RC3 combined) showing a significant temporal contiguity effect, with $F(2, 89) = 4.44, p = .007, \text{partial } \eta^2 = .091$. When looking at follow-up univariate analyses, most of the main effect was driven by the RC3 gyroscopic instruments measure, with $F(1, 90) = 5.88, p = .008, \text{partial } \eta^2 = .061$. Specifically, as hypothesized, participants in simultaneous conditions ($M = .86, SE = .05$) performed significantly better when compared to those in the sequential conditions ($M = .70, SE = .05$).

Color coding main effects. Hypothesis 3B was partially supported. Specifically, a significant main effect of color coding for the RC1 gyroscopic instruments measure, with $F(1, 90) = 2.78, p = .050, \text{partial } \eta^2 = .030^2$. As hypothesized, participants in the color conditions ($M = .82, SE = .02$) had significantly stronger RCs when compared to those in the no-color conditions ($M = .75, SE = .04$). Furthermore, albeit not significant ($F(1, 90) = 2.42, p = .062, \text{partial } \eta^2 = .026$), the same trend appeared for RC3 pitot-static instruments, with participants in the color conditions ($M = .65, SE = .04$) forming stronger RCs than those in the no-color conditions ($M = .53, SE = .06$).

Interaction of Temporal Contiguity and Color Coding on Instrument RCs

Hypothesis 5B was supported with the RC measures on pitot-static instruments (RC1 and RC3 combined) showing a significant interaction effect, with $F(2, 89) = 2.59, p = .041, \text{partial } \eta^2 = .055$. When looking at follow-up univariate analyses, both RC measures on pitot-static instruments yielded a significant interaction, which are reviewed next.

² The overall MANCOVA was not significant.

Training interaction on RC1 pitot-static. The RC1 pitot-static instruments measure showed a significant interaction effect, with $F(1, 90) = 3.48, p = .033, \text{partial } \eta^2 = .037$. Post-hoc tests using the Duncan Statistic showed a significant difference between participants who received simultaneous, color CBT ($M = .74, SE = .04$) and participants who received the simultaneous, no color CBT ($M = .59, SE = .06$), $p = .026$ (one-tailed), indicating, as hypothesized, that color would support the creation of RCs. However, this differential effect of color was not present for the sequential CBTs, with the sequential, color CBT ($M = .64, SE = .04$) showing no statistical difference from the sequential, no color CBT ($M = .67, SE = .06$) (See Figure 25).

Training interaction on RC3 pitot-static. Finally, the RC3 pitot-static instruments measure also showed a significant interaction effect, with $F(1, 90) = 4.22, p = .022, \text{partial } \eta^2 = .045$. Post-hoc tests using the Duncan Statistic showed similar results to those in previous interactions; that is, a significant difference between participants who received simultaneous, color CBT ($M = .69, SE = .06$) and participants who received the simultaneous, no color CBT ($M = .42, SE = .09$), $p = .009$ (one-tailed), indicating that color would support the creation of RCs. Similarly to the previous interaction, this differential effect of color was not present for the sequential CBTs, with the sequential, color CBT ($M = .60, SE = .06$) showing no statistical difference from the sequential, no color CBT ($M = .64, SE = .08$) (See Figure 26).

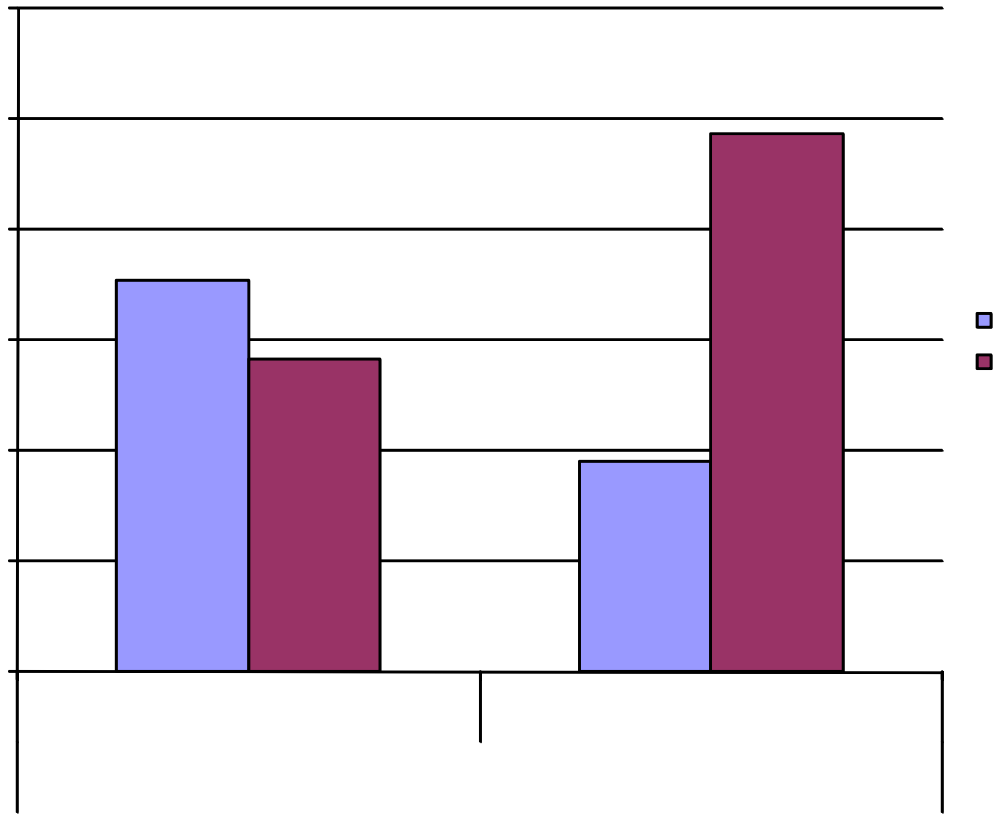


Figure 25. Temporal contiguity by color coding interaction on the RC1 pitot-static instruments knowledge measure.

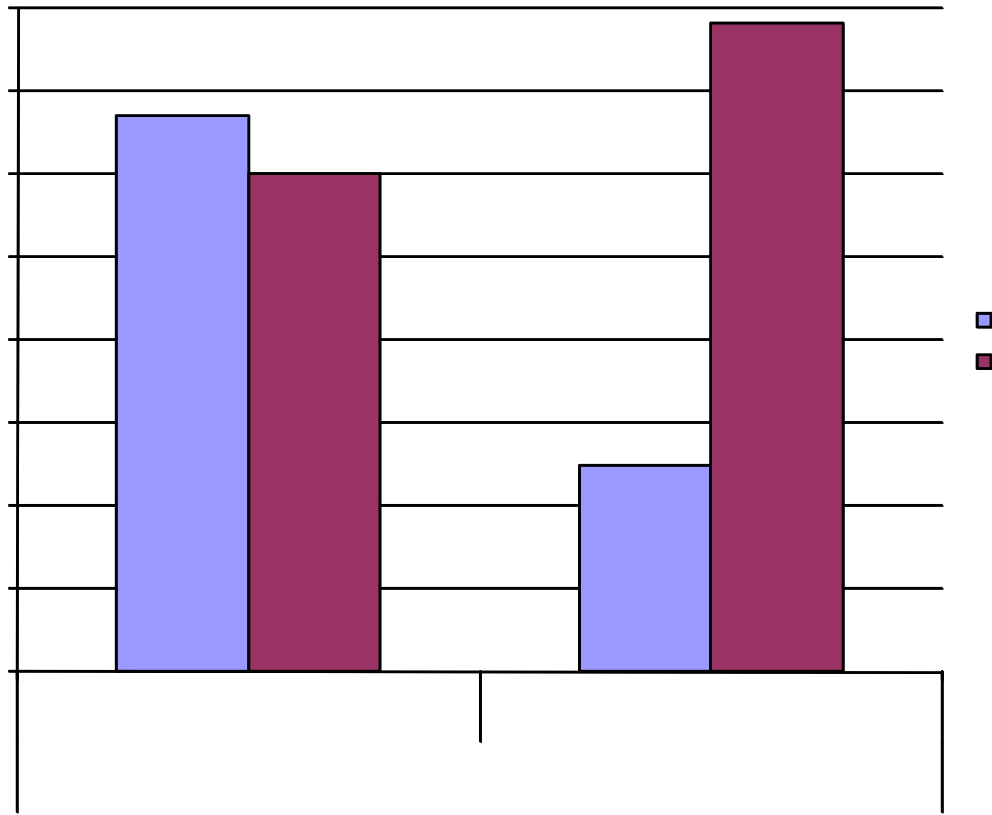


Figure 26. Temporal contiguity by color coding interaction on the RC3 pitot-static instruments knowledge measure.

Training Effects on a New RC Overall Instruments Aggregate

Finally, similarly to the new aggregate created to more completely assess training effects on cognitive learning outcomes, a new aggregate, RC instruments overall, was created by combining the four instrument aggregates that yielded significant effects (i.e., RC1 gyroscopic instruments overall, RC1 pitot-static instruments overall, RC3 gyroscopic instruments overall, and RC3 pitot-static instruments overall). The goal was to capture the variance from all RC instrument measures into a unique measure indicative of instrument RCs. Internal consistency, as measured by Cronbach’s *alpha*, was 0.635.

Univariate analysis revealed a significant main effect of color coding for the RC overall instruments measure, with $F(1, 90) = 2.84, p = .048, \text{partial } \eta^2 = .015$. Specifically, as hypothesized, participants in the color conditions ($M = .74, SE = .02$) performed significantly better when compared to those in the no-color conditions ($M = .67, SE = .03$).

Overall, the analyses of training effects on the relevant instruments RC measures reported in this section revealed that, indeed, training had significant main and interaction effects on those measures. In summary, not only had training significant effects on developing knowledge of instruments, but training also had significant effects on the corresponding instruments RC measures. Thus, the last section of this result section will assess the most important question posited in this dissertation: to what extent RCs mediate cognitive learning outcomes? And more specifically, to what extent is the development of instruments knowledge mediated by its relative RC measures?

RC Instrument Measures as a Mediator of Instruments Knowledge

RC Instrument Measures Correlations to Instruments knowledge Measures

Hypothesis 7A and 7B were fully supported, indicating that RC instruments measures did significantly correlate with relative instruments knowledge measures. A correlation matrix indicating the significance of RC instruments measures correlations to the declarative instruments measures is presented in Table 15, while Table 16 presents RC instruments measures correlations with integrative instruments measures. Finally, a significant correlation was also found between the overall instruments knowledge aggregate and the overall RC instruments measures, with $r(96) = .597, p < .001$. Thus, a significant relationship of RC instruments

measures with instruments knowledge measure was found. The next section, establishes the mediating nature of this relationship.

Table 15. *Matrix showing RC correlations with declarative measures*

	Declarative gyroscopic		Declarative pitot-static	
	<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>
RC1 gyroscopic	.36**	<0.01	.32**	<0.01
RC1 pitot-static	.31**	<0.01	.25*	0.01
RC3 gyroscopic	.36**	<0.01	.37**	<0.01
RC3 pitot-static	.21*	0.04	.26*	0.01

* *p*<.05 (one-tailed)
 ** *p*<.01 (one-tailed)

Table 16. *Matrix showing RC correlations with integrative measures*

	Integrative instruments		Integrative maneuvers	
	<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>
RC1 gyroscopic	.53**	<0.01	.52**	<0.01
RC1 pitot-static	.49**	<0.01	.36**	<0.01
RC3 gyroscopic	.45**	<0.01	.35**	<0.01
RC3 pitot-static	.51**	<0.01	.47**	<0.01

* *p*<.05 (one-tailed)
 ** *p*<.01 (one-tailed)

Statistical Technique used to Demonstrate Moderated Mediation

To establish mediation, Baron and Kenny’s (1986) procedure was used to determine if RC instrument measures indeed mediated the relationship between the interaction of the IVs with instrument knowledge measures. These procedures were divided into a three-step process. First, simultaneous regression was used to establish a correlation between the training manipulations and the instruments knowledge measures. The terms entered in this equation to predict

instruments knowledge measures were temporal contiguity (coded as 0 for successive and 1 for simultaneous), color coding (coded as 0 for no color coding, 1 for color coding), the interaction term of the two IVs, and the two CVs (i.e., verbal and spatial ability). Second, simultaneous regression was used to verify that a relationship exists between the training manipulations and the mediator variable (i.e., RC instrument measures). The terms entered in this equation were the same as the previous one; however, the predicted variable is the expected mediator. Third, a final simultaneous regression was performed to assess whether RC instrument measures fully or partly mediate the relationship of the training manipulations and the instruments knowledge measures. Specifically, the terms entered in this equation were the same as step 1, plus the RC term. If the mediator was significant then we have at least partial mediation. If the interaction term of the two IVs loses significance, then we have full mediation. Next, results are provided for each knowledge measure.

Knowledge and RC measures used in Multiple Regression Models

The cognitive learning outcome measures of interest were the three knowledge measures that showed to be significantly affected by the training manipulations, that is, the declarative gyroscopic instruments, the integrative instruments, and the aggregate of the two, overall instrument knowledge. Overall, the first step of the Baron and Kenny (1986) procedure revealed that all three knowledge measures were significantly predicted by the interaction of temporal contiguity by color coding (for example, see Tables 18, 20, and 22).

Next, the RC measures of interest were two new aggregates based on significance in the second step of the procedure. The first aggregate combined RC1 and RC3 pitot-static instruments into an overall RC pitot-static instruments measure. However, since this aggregate excluded both gyroscopic measures, and knowing that these gyroscopic measures were not significant, a second

overall aggregate, RC overall, combined all RC main aggregates (i.e., RC surface parts overall, RC maneuvers overall, RC axes overall, RC gyroscopic instruments overall, and RC pitot-static instruments overall) to capture the total variance of the RC measures. Thus, in spite of combining non-instrument sub aggregates, the RC overall aggregate provides insight on how RCs, globally, affected knowledge of instruments. The reliability of these two new aggregates is reproduced in Table 17, indicating moderate reliability considering the number of items. Overall, these two aggregates were significantly predicted by the interaction term in the second step of the Baron and Kenny (1986) procedure (see, for example, Table 18 and 19).

Table 17. *Reliability estimates of the two new RC aggregates*

Measure	N (items)	Alpha
RC pitot-static instruments	2	.658
RC overall	5	.689

Demonstration of Moderated Mediations

Hypothesis 8 was fully supported, showing that both RC aggregates fully mediated the IVs interaction with the three DVs (i.e., declarative gyroscopic instruments, integrative instruments, overall instrument knowledge). Specifically, when looking at the results by RC measures, the RC pitot-static instruments fully mediated training manipulations with the declarative gyroscopic instruments measure (Table 18), the integrative instruments measure (Table 20), and the overall instrument knowledge aggregate (Table 22).

Finally, the RC overall aggregate also fully mediated training manipulations with the declarative gyroscopic instruments measure (Table 19), the integrative instruments measure (Table 21), and the overall instrument knowledge aggregate (Table 23).

Table 18. *RC pitot-static instruments mediation with declarative gyroscopic instruments.*

Variables in Model	β	p	Adjusted R^2	F	p	ΔR^2	p
Step 1 (Predicting declarative Gyroscopic instruments)							
			.246	7.190	<.001		
Temporal contiguity	-.055	.393					
Color coding	-.093	.106					
Interaction	.163	.022					
Verbal ability	.498	<.001					
Spatial ability	.023	.031					
Step 2 (Predicting RC pitot-static Instruments)							
			.065	2.316	.050		
Temporal contiguity	-.081	.309					
Color coding	-.035	.622					
Interaction	.183	.033					
Verbal ability	.159	.331					
Spatial ability	.021	.109					
Steps 3 & 4 (Demonstrating Mediation)							
			.277	7.054	<.001	.037	.030
Temporal contiguity	-.030	.636					
Color coding	-.087	.123					
Interaction	.121	.066					
Verbal ability	.457	.001					
Spatial ability	.019	.064					
RC pitot-static instruments	.169	.015					

Note: the values in the grey areas are one-tailed

Table 19. *RC overall mediation with declarative gyroscopic instruments.*

Variables in Model	β	p	Adjusted R^2	F	p	ΔR^2	p
Step 1 (Predicting declarative Gyroscopic instruments)							
			.246	7.190	<.001		
Temporal contiguity	-.055	.393					
Color coding	-.093	.106					
Interaction	.163	.022					
Verbal ability	.498	<.001					
Spatial ability	.023	.031					
Step 2 (Predicting RC overall)							
			.157	4.530	.001		
Temporal contiguity	-.048	.252					
Color coding	-.023	.531					
Interaction	.095	.034					
Verbal ability	.260	.003					
Spatial ability	.009	.169					
Steps 3 & 4 (Demonstrating Mediation)							
			.277	10.261	<.001	.123	<.001
Temporal contiguity	-.024	.681					
Color coding	-.078	.139					
Interaction	.102	.171					
Verbal ability	.332	.010					
Spatial ability	.017	.083					
RC overall	.642	.000					

Note: the values in the grey areas are one-tailed

Table 20. *RC pitot-static instruments mediation with integrative instruments.*

Variables in Model	β	p	Adjusted R^2	F	p	ΔR^2	p
Step 1 (Predicting integrative instruments)							
			.166	4.792	.001		
Temporal contiguity	-.091	.160					
Color coding	-.041	.478					
Interaction	.139	.041					
Verbal ability	.133	.314					
Spatial ability	.037	.001					
Step 2 (Predicting RC pitot-static Instruments)							
			.065	2.316	.050		
Temporal contiguity	-.081	.309					
Color coding	-.035	.622					
Interaction	.183	.033					
Verbal ability	.159	.331					
Spatial ability	.021	.109					
Steps 3 & 4 (Demonstrating Mediation)							
			.360	9.917	<.001	.190	<.001
Temporal contiguity	-.037	.515					
Color coding	-.028	.580					
Interaction	.051	.240					
Verbal ability	.043	.715					
Spatial ability	.030	.002					
RC pitot-static instruments	.367	<.001					

Note: the values in the grey areas are one-tailed

Table 21. *RC overall mediation with integrative instruments.*

Variables in Model	β	p	Adjusted R^2	F	p	ΔR^2	p
<i>Step 1 (Predicting integrative instruments)</i>			.210	4.792	.001		
Temporal contiguity	-.091	.160					
Color coding	-.041	.478					
Interaction	.139	.041					
Verbal ability	.133	.314					
Spatial ability	.037	.001					
<i>Step 2 (Predicting RC overall)</i>			.157	4.530	.001		
Temporal contiguity	-.048	.252					
Color coding	-.023	.531					
Interaction	.095	.034					
Verbal ability	.260	.003					
Spatial ability	.009	.169					
<i>Steps 3 & 4 (Demonstrating Mediation)</i>			.502	16.945	<.001	.323	<.001
Temporal contiguity	-.044	.386					
Color coding	-.018	.689					
Interaction	.045	.468					
Verbal ability	-.124	.249					
Spatial ability	.028	.001					
RC overall	.988	.000					

Note: the values in the grey areas are one-tailed

Table 22. RC pitot-static instruments mediation with overall instrument knowledge.

Variables in Model	β	p	Adjusted R^2	F	p	ΔR^2	p
Step 1 (Predicting overall instrument knowledge)							
			.258	7.619	<.001		
Temporal contiguity	-.073	.186					
Color coding	-.067	.173					
Interaction	.151	.014					
Verbal ability	.316	.006					
Spatial ability	.030	.001					
Step 2 (Predicting RC pitot-static Instruments)							
			.065	2.316	.050		
Temporal contiguity	-.081	.309					
Color coding	-.035	.622					
Interaction	.183	.033					
Verbal ability	.159	.331					
Spatial ability	.021	.109					
Steps 3 & 4 (Demonstrating Mediation)							
			.383	10.818	<.001	.124	<.001
Temporal contiguity	-.034	.507					
Color coding	-.058	.200					
Interaction	.086	.178					
Verbal ability	.250	.018					
Spatial ability	.024	.004					
RC pitot-static instruments	.268	<.001					

Note: the values in the grey areas are one-tailed

Table 23. *RC overall mediation with overall instrument knowledge.*

Variables in Model	β	p	Adjusted R^2	F	p	ΔR^2	p
Step 1 (Predicting overall instruments knowledge)							
			.297	7.649	<.001		
Temporal contiguity	-.073	.186					
Color coding	-.067	.173					
Interaction	.151	.014					
Verbal ability	.316	.006					
Spatial ability	.030	.001					
Step 2 (Predicting RC overall)							
			.157	4.530	.001		
Temporal contiguity	-.048	.252					
Color coding	-.023	.531					
Interaction	.095	.034					
Verbal ability	.260	.003					
Spatial ability	.009	.169					
Steps 3 & 4 (Demonstrating Mediation)							
			.566	19.323	<.001	.268	<.001
Temporal contiguity	-.034	.439					
Color coding	-.048	.218					
Interaction	.074	.090					
Verbal ability	.104	.267					
Spatial ability	.022	.002					
RC overall	.815	<.001					

Note: the values in the grey areas are one-tailed

Summary of the Results

Figure 27 presents the pattern of results obtained in this dissertation, using the example of the attitude indicator as part of the airplane instruments. Specifically, when reading the figure from left to right, the training manipulations (simultaneous versus sequential, color versus no color) affected both RC1 and RC3 for instruments, which were the two RCs that measured instruments. For each RC measure, a visual thumbnail is presented showing an example of an attitude indicator question. Below each representative question, a thumbnail representation of the pattern of results for the interaction is provided. Next, the two RCs mediated the effect of the manipulations on both declarative and integrative knowledge. Again, a visual thumbnail is offered for each type of question, along with its respective interaction pattern (recall that, although not illustrated below, the integrative questions required the participants to diagnose the maneuver illustrated by the instrument panel readout). Overall, Figure 27 reflects how training affected RCs, which, in turn, mediated training effects on cognitive learning outcomes.

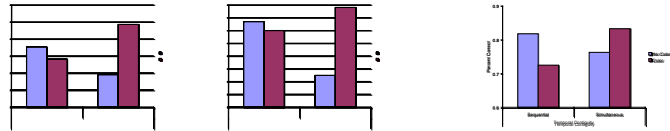


Figure 27. Pattern of results example using the simultaneous-color training variation and the concept of the attitude indicator. The graph show the actual pattern of results obtained at each levels.

CHAPTER 5: DISCUSSION

The primary motive of this dissertation was to address the issue of indirectly assessing cognitive processes by directly measuring referential connections to (a) verify the presence of referential connections, and (b) to measure the extent to which referential connections affected cognitive learning outcomes. First, the challenge was to create valid and reliable measures that would gauge RC strength. This task was difficult in part because there has not been an effective and direct attempt to measure RCs in the past. Second, an appropriate multimedia CBT had to be developed to test the impact of RCs on learning. Third, knowledge measures had to be developed to assess mastery of the concepts learned in the CBT.

Overall, these three main foci (i.e., developing RC measure, multimedia CBT, and knowledge assessment) are discussed in relation to the results obtained along with their respective implications regarding the various multimedia models presented in this dissertation. Specifically, in this discussion I first review how RC and knowledge measures were developed. Then, I present how the CBT was developed in conjunction with the chosen training manipulations. A discussion follows on the interpretation of the current results in relation to the integrated multimedia framework presented in the Introduction. Next, a discussion is offered on the role of RCs within the main multimedia learning models, followed by theoretical and practical implications. Finally, a section is provided on the limitations of this dissertation as well as directions for future research.

Measures and Multimedia CBT Development

The intent of this section is to assess the overall effectiveness of developing RC measures, the multimedia CBT, and the knowledge measures. Together, these three elements build the common thread in this dissertation. That is, with the focal point being RCs, it was necessary to develop a multimedia CBT along with design manipulations that would affect these RCs. Furthermore, knowledge measures development was just as important to verify the extent to which RCs mediated the interaction of training manipulations and cognitive learning outcomes.

Psychometric Evaluation of RC Measures

Prior to this dissertation, RC evidence was inferred by assessing the impact of training manipulations of cognitive learning outcomes. This lack of direct evidence was remediated by attempting to develop direct RC measures. The goal of measuring RCs, as described earlier, was to: (a) directly gauge RCs, and (b) assess the link between RC strength and cognitive learning outcomes. Furthermore, RCs were measured in three different ways: (a) with an implicit association measure (RC1) showing audio / visual associations that can be either correct or incorrect, (b) with a rating-scale measure (RC2) in which trainees were asked to rate the extent to which a connection existed between the presented text concept and visual aid, and (c) with a recognition measure (RC3), in which trainees were presented with the text and visual aid concepts similarly to the RC1 measure, albeit in a multiple choice format.

RC1. RC1 was an adaptation of the Implicit Association Test (IAT) (see Greenwald, Nosek, & Banaji, 2003). This measure assessed the RC construct by asking participants to respond as fast as they could on the accuracy of text / visual aid presented pairs. Overall, RC1 displayed the lowest reliability of the three measures, with an internal reliability coefficient of

.66. Two factors may have contributed to this arguably weak internal consistency score. First, RC1 was the first RC measure, which was preceded by the verbal and spatial aptitude measures. Thus, a variation of the practice effect may have occurred for the following two RC measures. In other words, since both RC2 and RC3 presented virtually the same text and visual concepts, although with different methods, these two measures may have benefited from the exposure to these text and visual concepts in the RC1 measure. Second, RC1 also asked participants to promptly answer each item, which may have increased workload, thereby further affecting participants' answers. However, theoretically, RC1 represents the most direct approach to gauging RC strength used in this dissertation in that it prevented participants from elaborating on each item, thereby, providing answers that should reflect the dual-coded nature of RCs. Furthermore, RC1 was successfully used, as discussed later, to show moderation between the training manipulations and the knowledge measures. In sum, in spite of its weak internal consistency, the method used in RC1 successfully evaluated a portion of the overall RC construct. As a result, this measure's methodology remains warranted when investigating RCs.

RC2. The second RC measure (i.e., rating-scales RC), had participants exposed to text / visual aid concept pairs and subjectively rate how strongly they felt a connection existed between the two presented pair elements (i.e., text concept and visual aid concept). This measure yielded the highest internal consistency score, with Cronbach's *alpha* = .88. For the reasons discussed with the RC1 measure, RC2 may have benefitted from the exposure to the text concepts and the visual aid concepts. Psychometrically, using a range for the responses instead of a dichotomous response such as in RC1 also contributed to yield higher internal consistency scores. Thus, the high internal consistency of the RC2 measure indicates that this is an appropriate method to gauge the RC construct. Unfortunately, as discussed alter, only instruments knowledge measures

were successfully affected by the training manipulations, and since RC2 did not have any instruments items, this highly reliable scale was not used to assess mediation. In sum, the methodology used in the RC2 measure successfully captured a portion of the overall RC construct, thus, is warranted for future RC investigations.

RC3. The last RC measure, a recognition measure, had trainees evaluate the extent to which they could accurately identify concepts in a multiple-choice type of format. This measure offered another way to gauge the strength of referential connections, since its format asked learners to identify the correct combination of text concept with its corresponding visual concept among four possible choices. Overall, this measure yielded an acceptable internal consistency score, with Cronbach's *alpha* = .76. However, in light of the practice effect argument, this measure did not seem to have benefited as much from it than the RC2 measure. Theoretically, the RC3 measure may be the one that least *directly* measures the construct of RC since it allows participants more time to elaborate on each item by comparing the four possible choices. However, the reliability is still higher when compared to the RC1 measure; thus, RC3 effectively gauged a portion of the RC construct. The notion of RC3 being an appropriate measure to gauge RCs was further validated by finding that it mediated the interaction of the training manipulations and the instruments knowledge measures (discussed in detail in a further section). In sum, the method used for the RC3 measure is warranted for further studies investigating RCs.

Knowledge Measures Psychometrics

Two knowledge measures were created to assess the mastery of the concepts taught in these categories at various levels of elaboration, ranging from factual knowledge to application of knowledge with a transfer-like measure. Furthermore, these knowledge measures rated performance on a percentage scale. This zero-to-one-hundred scale is widespread in academia,

and more specifically, it is also the adopted range for grading the FAA written exam, which aspiring pilots have to pass as a step towards obtaining a private pilot's license. This point is particularly important, because it helps ground the reported means in the result section in a real-life context. Specifically, a ten percentage point difference between means indicates a difference in letter grade in academia; also, it happens that the passing grade for an FAA's written exam test is seventy percent. As a result, when looking at the figures in the results section the represented range was adjusted to emphasize mean differences. The specific scores obtained with these measures are reported below, in the section on the discussion of the main findings.

Declarative measure. A declarative measure was developed to evaluate learners' understanding of conceptual and factual knowledge from the multimedia CBT. This measure involved low level of elaboration (e.g., Fiore et al., 2003), which, may occasionally be unable to diagnose differences in learning across training manipulations. The multiple-choice method employed to assess declarative knowledge is widespread in academia and presents questions about factual knowledge of a given concept that participants have to answer by selecting a correct answer from a number of possible responses. This measure obtained an acceptable internal reliability estimate of .77, using Cronbach's *alpha*, indicating that declarative knowledge was effectively measured. In sum, when evaluating cognitive learning outcomes, the use of declarative measures is warranted in order to capture a portion of participant's mastery of concepts.

Integrative measure. Integrative measures typically indicate participants' ability to relate declarative knowledge of concepts together (e.g., Jonassen & Grabowski, 1993). In this dissertation, integrative knowledge involved a higher level of elaboration when compared to declarative measures. Two integrative measures were developed. The first one (integrative

instruments), gauged participants' ability to read different clusters of animated instruments. Overall, this measures' internal consistency score was .72, using Cronbach's *alpha*, indicating acceptable reliability. Thus, this methodology of showing animated instruments clusters to participants effectively gauged participants' understanding of the relationship between instruments; thus, represents an appropriate method to assess integrative knowledge of instruments. Furthermore, results in this dissertation have shown that training manipulations affected this integrative measure (discussed in the main findings section).

The second integrative was more akin to a transfer task in which participants had to apply their knowledge of the learned concepts. Specifically, participants watched short movies of an airplane performing various maneuvers, and they had to infer what surface parts and instruments were most affected as a result. Overall, this measures' internal consistency score was .61, using Cronbach's *alpha*, indicating acceptable reliability given the fact that it was based on ten items. Unfortunately, training manipulations did not affect this measure. A possible reason for this shortcoming was that on average participants did not perform well on this type of measure ($M = .45$, $SD = .22$). As a result, a restriction of range ensued, which may have prevented the measure to be sensitive enough to the training manipulations. However, this type of measure methodology (i.e., presenting a video or animation of an airplane) showed to be sensitive to training manipulations in previous studies (e.g., Cuevas et al., 2002, 2004; Fiore et al., 2002, 2003, 2004). In sum, this dissertation partially validated the use of integrative measures; however, in light of previous successful use of integrative measures in other studies, their use is warranted since they evaluate an important aspect of knowledge.

Multimedia CBT

The goal of this multimedia CBT was to create an effective platform to convey multimedia information. This was based upon an elaboration of earlier multimedia CBT testbeds developed by TPL (see Cuevas et al., 2002, Fiore et al., 2003; Scielzo et al., 2006; Scielzo, Fiore, Cuevas, & Klein, 2003). Furthermore, material for the multimedia CBT was adapted from the Jeppesen Sanderson Private Pilot Manual (1996) and the Jeppesen Sanderson Private Pilot Maneuvers Manual (1996), both standard training products for the instruction of pilots in the private and public sector. As a result, the content of the CBT was previously validated.

The instructional theory used to develop those modules was based on Mayer's (1999b) constructivist learning, which aimed at supporting SOI working-memory processes (i.e., selection, organization, and integration). In this dissertation, SOI processes (thought to influence RCs) were further affected by the two experimental manipulations (i.e., temporal contiguity, and color coding). As a result, the next section – a discussion on the main findings in this dissertation – focuses on commenting on the overall effect of each training variation on the development of both RCs and knowledge, as well as exploring the extent to which RCs mediated the relationship between training manipulations and cognitive outcome measures.

Discussion of Main Findings

This section follows the organization of the results section. First, I provide a summary of the results pertaining to the impact of the training manipulations on the cognitive learning outcomes. Second, I summarize the effects of training on RCs. For these two sections (i.e., training on outcomes, and training on RCs), the hypotheses were as follows: (a) a simultaneous

presentation would support learning, while a sequential one would hinder it, and (b) color coding would support learning, while the absence of color would hinder it. Finally, I document how, as hypothesized, RCs did mediate cognitive learning outcomes. For this final section, the hypotheses were that not only RCs would significantly correlate with outcome measures, but the RCs would show (full) mediation as well.

The goal of this section is to report on the results in the context of the specific training manipulations, RCs, and knowledge measures. Following this discussion on the main findings, a commentary is provided on the results obtained in this dissertation in terms of (a) the integrated multimedia framework (SOI processes and cognitive attention limitations), and (b) the multimedia models presented in the Introduction.

The impact of Training Manipulations on Cognitive Learning Outcomes

The training manipulations successfully affected the learning of airplanes' primary instruments, as measured by the declarative gyroscopic instruments measure and the integrative instruments measures. The declarative gyroscopic instruments measure evaluated knowledge of these instruments by asking specific questions regarding the attitude indicator, the heading indicator, and the turn coordinator. The integrative instruments measure presented different clusters of animated instruments, and learners had to infer the state of the plane. The training manipulations did also affect the overall instrument knowledge aggregate that was developed to capture the variance across declarative and integrative questions.

The declarative measure, as hypothesized, showed a significant interaction of temporal contiguity by color coding was found, with the results indicating that color coded information yielded better performance on the declarative measure when information was presented simultaneously ($M = .83, SE = .03$) when compared to sequentially ($M = .76, SE = .05$).

Conversely (and not predicted quite as such), the absence of color helped performance on the declarative measure when the information was presented sequentially ($M = .82, SE = .04$) when compared to sequentially presented information that was not color coded ($M = .72, SE = .03$).

The same pattern of results was found a significant interaction of temporal contiguity by color coding on the integrative instruments measure and the instruments knowledge aggregate. Specifically, the same expected color coding effect was found on the integrative measure when training information was color coded and presented simultaneously ($M = .68, SE = .03$) as opposed to not being color coded ($M = .58, SE = .05$); but, unexpectedly, the absence of color coding helped in the sequential condition ($M = .67, SE = .05$), when compared to color coded information ($M = .63, SE = .03$). Similarly, when looking at the interaction effect on the instruments knowledge measure, color coded information that was presented simultaneously yielded better knowledge scores ($M = .76, SE = .03$) when compared to information that was not color coded ($M = .67, SE = .04$). The same reverse effect was found for the absence of color coded information being helpful when information was sequentially presented ($M = .75, SE = .04$) and not helpful when the information was color coded ($M = .68, SE = .03$).

When looking at these means, the lack of main effect for temporal contiguity and color coding was due to the crossover interaction pattern (represented in Table 24). Possible theoretical interpretations of these results are offered in the section, below, on the integrated multimedia framework and models.

Table 24. *Directional effect categorization of color coding by temporal contiguity on the declarative, integrative, and instrument knowledge measures.*

		Color Coding	
		No Color-Coding	Color-Coding
Temporal Contiguity	Simultaneous	<i>hindrance</i>	<i>beneficial</i>
	Successive	<i>beneficial</i>	<i>hindrance</i>

The impact of Training Manipulations on the Creation of RCs

Since the training manipulations had significant effects on the instruments knowledge measures, it was important to verify that RC instrument measures were similarly affected. In fact, if RCs did indeed mediate learning between training and learning, training should have affected RCs in much the same way it did with knowledge measures, since RCs were thought to support knowledge. Overall, there were four RC measures of instruments, divided by two types of RC methods (i.e., RC1 and RC3 only, since RC2 did not have any instruments items), and two types of instruments (i.e., gyroscopic and pitot-static). Furthermore, a global RC instruments aggregate was computed to capture the overall variance of the effects of training across RC measure (i.e., RC1 and RC3).

Training manipulations did reveal main effects for temporal contiguity and color coding, in the expected direction, on RC measures, when such main effects were not found on the previous section on knowledge measures. Specifically, a main effect of temporal contiguity was found on the RC3 gyroscopic instruments measure, indicating that training participants with a simultaneous presentation of modalities resulted in stronger RC scores ($M = .86, SE = .05$) when compared to participants trained with sequentially presented information ($M = .70, SE = .05$). Furthermore, a main effect of color coding was also found on both measures of gyroscopic

instruments, as well as the overall RC aggregate, indicating that when training information was presented simultaneously ($M_{RC1} = .82$, $SE_{RC1} = .02$; $M_{RC3} = .65$, $SE_{RC3} = .04$; $M_{RC} = .74$, $SE_{RC} = .02$), RCs were stronger than when information was presented sequentially ($M_{RC1} = .75$, $SE_{RC1} = .04$; $M_{RC3} = .53$, $SE_{RC3} = .06$; $M_{RC} = .67$, $SE_{RC} = .03$). Overall, finding both temporal contiguity and color coding main effects in the expected directions for the RC instruments measures may be an indication that the creation of RCs was more sensitive to temporal and color manipulations than the cognitive learning outcomes.

Training manipulations also interacted on both RC pitot-static measures (i.e., RC1 and RC3 pitot-static instrument measures). The significance of the interaction was driven by the differential impact of color coding, in the expected direction, within the simultaneous presentation condition. That is, color coded information supported the creation of RCs when temporal contiguity was simultaneous ($M_{RC1} = .74$, $SE_{RC1} = .04$; $M_{RC3} = .69$, $SE_{RC3} = .06$) and hindered RCs when the information was not color coded ($M_{RC1} = .60$, $SE_{RC1} = .06$; $M_{RC3} = .43$, $SE_{RC3} = .09$). The difference from the knowledge measures resided in that the color coding manipulation did not affect the sequential condition. This result is important because it indicates that color coding affected RCs and cognitive learning outcomes differently. Specifically, while color coding impacted both RCs and cognitive learning outcomes in the expected direction when the presentation of information was simultaneous, the impact was reversed in the sequential condition for cognitive learning outcomes, only. This, in turn, may indicate that color coding may have a differential effect on working memory mechanisms. A theoretical explanation of these results is provided below, in relation to the multimedia integrated framework and multimedia learning models.

Table 25. *Directional effect categorization of color coding by temporal contiguity on the RC1, RC3, and overall RC instruments measures.*

		Color Coding	
		No Color-Coding	Color-Coding
Temporal Contiguity	Simultaneous	<i>hindrance</i>	<i>beneficial</i>
	Successive	<i>neutral</i>	<i>neutral</i>

RCs Mediating Cognitive Learning Outcomes

The ultimate goal of this dissertation was to verify that RCs would mediate learning. Overall, strong correlations were found between instruments knowledge measures and RC instruments measures. However, since correlation offers limited insight into variable relationships, the Baron and Kenney (1986) procedure was adopted to test for mediation. As a result of the first two steps in this procedure, two new aggregate measures were computed: one that grouped both RC1 and RC3 pitot-static instruments measures since they were predicted by the interaction of temporal contiguity by color coding, and another one that created an overall RC measure, which was also predicted by the interaction of temporal contiguity by color coding. This last measure (i.e., RC overall) was created to see to what extent RCs, as a whole, mediated knowledge on instruments measures that were also predicted by the interaction of temporal contiguity by color coding. In this case, these instruments measures were the same ones that were affected by the training manipulations; that is, the declarative gyroscopic instrument measure, the integrative maneuvers measure, and the instruments knowledge aggregated measure.

Evidence of mediation was found for the two RC aggregated measures. Specifically, mediation by the RC pitot-static aggregate indicated that it was necessary to develop strong RCs

for the pitot-static instruments in order to perform well on the three instruments knowledge measures. More importantly, the full mediation shown for the overall RC aggregate, which evaluated RC strength on all the main training components (i.e., airplane surface parts, maneuvers, axes of flight, and instruments) had a stronger impact, indicating that overall strong RCs were necessary to achieve high scores on the three instruments knowledge measures. In sum, results indicated that both RC aggregates mediated learning on all three instrument measures. Thus, these results support the notion that strong RCs may lead to accurate knowledge. Implications of these results are discussed in the next section.

Multimedia Learning Framework

Most theoretical models presented in the introduction inferred the existence of RCs by looking at how different multimedia training variations could affect cognitive learning outcomes. With this dissertation, a comprehensive theoretical view was offered, detailing the manner in which the three main SOI working memory processes of information selection, organization, and integration supported the creation of RCs. To empirically verify that RCs existed and to assess to which extent they do mediated learning within a multimedia CBT paradigm, RC measures were developed and validated, as indicated by the psychometrics results. Furthermore, the creation of RCs could be further supported or hindered according to the temporal arrangement of modalities as well as the color coding of such modalities. These two training manipulations were chosen because, based on a large body of empirical support, they were likely to differentially affect RC creation and learning; thereby, providing insight into this relationship.

Implications for an Integrated Multimedia Learning Framework

The integrated multimedia framework borrowed concepts from the CTML model and the HIP model to provide insight into the three main SOI processes (i.e., selection, organization, and integration of information). The aim of this framework was to be better able to diagnose the effects of training manipulations on RCs. Overall, the results obtained in this dissertation were not all successfully predicted by this integrated framework. Next, a review of the result findings is provided as they related to SOI processes and cognitive attention limitation.

Selection of information. Results suggest that selection of information may be important to support RC creation. Specifically, it was hypothesized that simultaneous presentation of information would support selection of information more so than when information was presented sequentially in large part due to the decrease in workload when trying to combine text and visual information together in a dual-coding fashion to create RCs. Overall, results have shown that only the RC3 gyroscopic instruments measure yielded a significant main effect on temporal contiguity, with a difference of 16% in the expected direction. Another main effect of temporal contiguity, reported in Appendix A, found a difference of 8% in the expected direction for RC1 surface parts measure. All other RC and knowledge measures did not show any significant main effect for temporal contiguity.

It was also hypothesized that color coded information would support information selection as a pre-attentive technique that does not draw on cognitive resources. Again, only three RC measures were able to show a main effect of color coding in the expected direction (7% difference for the RC1 gyroscopic instruments measure, 13% difference for the RC3 pitot-static instruments measure, and 7% difference for the RC overall aggregate). All other measures, including knowledge measures did not show any main effect for color.

More troubling are the results of the interaction of temporal contiguity by color coding for the RC measures. That is, as it was shown in the results, most main effects were lost due to the crossover interaction pattern that indicated a reverse effect of color coding for sequentially presented information. There are a number of possible explanations for this differential effect of color on RCs when temporal contiguity varies, but none satisfactorily explain this particular finding. First, the crossover pattern was pronounced only for the instruments knowledge measures and not for the RC measures (i.e., RC1 pitot-static instruments measure, RC3 gyroscopic instruments measure, and, as reported in Appendix A, RC3 surface parts); which showed that it made no difference whether or not color coding was used for the sequentially presented information, with a difference of 4% on these RC measures. These results suggest that measures looking at different cognitive processes or outcomes (in this case RCs or cognitive learning outcomes) may be differentially affected by interacting design factors (in this case temporal contiguity and color coding). This leads to the second point that it is always more difficult to predict the combined effects of two or more factors when compared to looking at main effects in isolation. In sum, not all predictions stemming from a theoretical understanding on how multimedia information is selected were supported. A discussion on how interacting design factors need to be better understood is provided in a section below on practical implications.

Organization of information. Results did not offer any valuable insight into the organization process. LTM and attention resources are thought to be heavily used when organizing information. Thus the expectation that paired color coding would offer an advantage when compared to the use of non-paired color coding in terms of use of less cognitive resources. Results have shown that this was not the case on any of the measures used in this dissertation.

However, partial support was found for those measures that were affected by temporal contiguity. Specifically, organization of information was hypothesized to be easier, in terms of cognitive resource used, when presentation was simultaneous, and harder when presentation of information was sequential.

Integration of information. Results indicate that this process may be pivotal for the successful development of RCs. Specifically, this process is thought to be – according to many multimedia learning models – the point at which information from both working memory stores (i.e., verbal and visual) converge and get encoded into LTM. Thus, by demonstrating a differential effect of training manipulations on RCs, it is possible to speculate that, indeed, the integration working-memory process may be responsible for creating RCs. In other words, the results in this dissertation indicate that strong RCs may indirectly support the notion of an integrative process.

Theoretical Implications

Predictions from the integrated multimedia framework, which combined a description of SOI processes and attention resources were not all supported by the results found in this dissertation. Specifically, the support or hindrance of working memory processes, based on the manner in which multimedia information was presented, had a direct, measurable effect on the overall strength of RCs. However, an important theoretical contribution this dissertation brought forth was supporting the existence of RCs (i.e., the outcome of combining the textual and visual representation of a concept in a dual coding fashion). Furthermore, RCs have shown to mediate learning indicating that strong RCs may be essential for the successful integration of information in LTM.

The integrated theory of multimedia learning brought forth in this dissertation offered a comprehensive attempt at describing the main factors involved in multimedia learning. Specifically, by combining Paivio's (1986) DCT, Mayer's (2001) CTML, and Wickens' (1997) HIP model, within Mayer's (1999b) SOI constructivist learning theory, this dissertation brought forth an attempt to predict RC behavior and how it would affect learning. Just as important is the notion of integration that some cognitive learning models bring forth. Specifically, Both Mayer (2001) and Baddeley (2001) have theorized about the importance of integrating information from both verbal (e.g., narration, text) and visual (e.g., pictures, animations, etc.) stores as a necessary precursor to learning. In this dissertation, I have argued that RCs are the result of this integration process. Furthermore, due to temporal precedence and a random assignment design, the results in this dissertation are consistent with the notion that RCs are indeed the result of integrating information from the verbal and visual stores. In turn, these RCs have also shown to mediate learning. Thus, an important theoretical contribution this dissertation provides is that (a) it supports the notion of dual-coding integration of information, and (b) it moves one step closer to the working memory "black box."

Practical Implications

Instructional Theory

The training materials developed for this dissertation followed the prescriptive approach of Mayers' (2001) principle of temporal contiguity, and Seufert and Brunken (2006) SLH technique of color coding; which is a pre-attentive technique ubiquitously used (e.g., Kalyuga, Chandler, & Sweller, 1999; Kozma, 2003; Tabbers, Marteens & van Morrienboer, 2004). However, the CBT developed for this dissertation was only partially successful since training

manipulations had a significant effect for the portion of the training teaching airplane's primary instruments. Arguably, the step taken to translate learning theory, which is descriptive in nature, into training materials, which is based on instructional principles and guidelines, may be the most difficult one. Principally, this is in large part due to (a) the many mental processes involved in learning that need to be accounted for when developing principles and instructional guidelines, and (b) the large variability imposed by learner's individual differences, such as verbal and spatial ability, that need to be factored-in to accurately predict learning outcomes. As a result, due to the findings in this dissertation, a number of instructional design guidelines can be proposed.

Instructional Design

Advancing multimedia learning theory is fundamentally vacuous if its application does not translate into useful design principles and guidelines. In turn, these principles and guidelines have to support the various cognitive mechanisms to successfully help learners acquire knowledge; hence, the paramount importance of instructional design.

The principles of temporal contiguity and color coding were supported to a certain extent, as described in previous sections. This finding illustrates that, while it may be easier to implement design factors in isolation, when combining two or more design factors together, cognitive outcomes may be less straightforward to predict. Thus, more research is warranted on the combined effect of training design variations to better understand the dynamic nature of how multimedia information is processed within a training paradigm.

Finally, another main source of variability that needs to be accounted for when designing multimedia training interfaces is, as mentioned earlier, the individual aptitudes that learners have. In this dissertation, two of the prevalent individual aptitudes – spatial and verbal ability –

were covaried-out to parse out that source of variability in order to better focus on the relationship between RCs and learning. Specifically, as described in the Introduction, spatial and verbal ability tend to affect how information is processed, when that information presents a mix of complex conceptual knowledge (see Cuevas et al., 2002) and requires understanding of complex spatial relations (see Fiore et al., 2003). Thus, when designing multimedia CBTs, individual differences need to be taken into considerations. Indeed, the one-size-fits-all approach to developing multimedia instructional material can be detrimental to learning. As a result, promising future venues of multimedia instructional design focus on adapting the multimedia interface according to the individual predispositions of the learner. For example, *intelligent tutoring systems* as defined by Akras and Self (2002) automatically adjust the training to match learners' aptitudes and skills. Another potential method that does not rely on an adaptive CBT system aims at training and improving learner's aptitudes. For example, successful training of spatial aptitude was achieved, indicating that it is possible to improve upon individual aptitudes (e.g., Kass, Ahlers, & Dugger, 1998; Rehfeld 2006).

Experiment Limitations

Color Coding

The two color manipulations (i.e., paired color coded information versus not-paired color coded information) did not reveal any significant differences on any of the cognitive learning outcomes or RC measures. Theoretically, the notion that paired-color coding would further facilitate the learning of concepts based on the pre-attentive support of the selection and organization of working memory processes was not verified. It may be that this specific training paradigm was not conducive to detect changes between these two color conditions. It may also

be that the measures used were not sensitive to changes in paired-color versus non-paired color information. Additionally, it may also be that the benefit of pre-attentive cueing provided by any of the two color coding variations (i.e., paired and non-paired color coding) outweighed the partial enhancement that came from the paired color coding. In other words, it may be that the pre-attentiveness of color was driving most of the beneficial effect on supporting RC development. However, theoretically, the distinction between paired-color coded information and non-paired color coded information is still warranted. Unfortunately, this distinction did not carry any noticeable effect in this dissertation. Thus, further empirical investigations of this concept are needed to verify in what specific circumstances this color manipulation has a measurable effect on learning.

Generalization Concerns

The results found in this dissertation were obtained from the manipulation of temporal contiguity and color coding on a multimedia CBT developed to teach the principles of flight to novices. Some of the main characteristics of this domain are (a) a high level of complexity in both the number of concepts to be mastered and the difficulty of those concepts, (b) the high level of concept interactivity, and (c) the visual nature of most concepts in the training. Thus, the findings in this dissertation may only be applicable to domains that share the same characteristics. In other words, multimedia CBTs on simpler domains may yield different results. However, theoretically, both temporal contiguity and color coding have shown robust results, regardless of the domain training (e.g., Kalyuga et al., 1999; Mayer, 2001). Another limitation involves the use of university students, which some examples of limits are, in comparison to the population, age and cognitive skills variability; thus, limiting the generalization of such sample.

Training Goals Issues

A limitation of this dissertation was that not all training main topics, in terms of learning objectives, were successfully affected by the CBT manipulations. In fact, of the five main topics (i.e., airplane surface parts, maneuvers, axes of flight, gyroscopic instruments, and pitot-static instruments) only the two instrument sub-sections were affected. An explanation for why the other knowledge measures evaluating airplanes surface parts, maneuvers, and axes were not affected by the training manipulations can only be speculative. That is, the same instructional design techniques were used for all sections of the CBT. However, a particular aspect of the instrument section is that it was the last section of training, and that knowledge of previous sections was necessary to properly understand instruments functioning. In other words, instruments indicate the airplane's state as it flies. Thus, to properly read an instrument it is necessary to understand how a plane changes its state as it flies; thereby, requiring a working knowledge of airplane parts and dynamics. As a result, it is possible that cognitive outcome measures may have been more sensitive to the instrument's knowledge. An important element for future consideration, in order to validate this concept, would be to add more modules to the multimedia CBT that would also require a working knowledge of the concept presented in previous sections (e.g., Visual Flight Rules or Instruments Flight Rules training) and verify that measures of knowledge from these added modules yield the same effects from the training manipulations.

Other Statistical Limitations

A number of limitations need to be considered. First, by collapsing two of the three color conditions, unequal cell sizes may have had a negative impact on the results. Second, although some of the measures used were both negatively skewed and with low reliability; these were

limited, and, furthermore, the use of multivariate statistics was robust enough, and the sample size used in this dissertation large enough, to compensate for these isolated weaknesses. Finally, not all RC measures shared the same sub-measures; thus, a complete Multi-Trait Multi-Method approach could not be employed. For example, RC2 did not have any of the instruments categories represented.

Directions for Future Research

There are a number of areas that, in light of the results in this dissertation, warrant more empirical investigation. This section is divided into (a) directions for future research based on training manipulations thought to influence RCs and learning, as they related to the main theoretical models presented in the Introduction, and (b) directions for future research based on ameliorating RC measures, in light of the psychometric results obtained in this dissertation.

Training Manipulations, Multimedia Learning Theory, and RCs

The pattern of results obtained in this dissertation was the consequence of the chosen manipulations aimed at differentially affecting RCs and learning via the support or hindrance of SOI working-memory processes. However, in the Introduction a number of other factors were introduced that, theoretically, would also affect RCs. Thus, I would like to present these factors, organized by theoretical model and relevance to SOI processes, as other means to investigate the relationship among training manipulations, RCs, and cognitive learning outcomes.

DCT factors. Paivio's (1986) dual-coding theory brought forth two important factors that were randomized or fixed in this dissertation: Information units and abstract versus concrete information presentation. Future research should manipulate the size (i.e., small versus large) and complexity (i.e., simple versus complex) of the information presented in a multimedia CBT to

gauge how it would differentially affect RC formation. In relation to SOI processes, small and simple information would be beneficial, while large and complex information would be detrimental to RC formation. Furthermore, future research should investigate the presentation of abstract versus concrete information to assess whether a break-down in RC formation occurs when the information is mostly abstract; thereby negatively affecting SOI processes, and how learning is affected as a consequence. Table 24 summarizes these factors and their impact on SOI processes and RCs.

Table 26. *DCT factors in relation to possible manipulations and expected effect on SOI and RCs.*

DCT factors	Manipulation	Expected effect on SOI and RCs
Information units	Small versus large, and simple versus complex	Positive impact of small and simple units Negative impact of large and complex units
Information presentation	Abstract versus concrete	Negative

CTML factors. In this dissertation, temporal contiguity was manipulated due to Mayer's (2001) cognitive theory of multimedia learning indicating that the sequencing in time of presented information would differentially affect learning. However, there were other factors that need further investigation to see what impact they have on SOI processes and RC formation. First, spatial contiguity (i.e., whether text and corresponding visual aids are spatially close or far from each other) may arguably be the most important factor requiring closer scrutiny. The question is how spatially distant can corresponding text and visual aids be without negatively affecting SOI processes and RCs. Next, the modality principle can be manipulated to assess whether narration and visual aids (parallel information acquisition) and text and visual aids (successive information acquisition) do differentially affect the creation of RCs. Parallel information would support SOI processes, while successive information would not. Another factor that may impact SOI processes, information coherence, addresses the question of the

relevance of the information presented. Specifically, future research should investigate the presentation of information with or without extraneous noise (visual, narrated, or written).

Theoretically, it would be important to assess to what degree some extraneous information could still be present without negatively affecting SOI processes, and, as a result, RC creation.

Table 27. *CTML factors in relation to possible manipulations and expected effect on SOI and RCs.*

CTML factors	Manipulation	Expected effect on SOI and RCs
Spatial contiguity	Integrated versus non-integrated text and visual aids	- Integrated: support SOI and RCs - Non integrated: hinders SOI and RCs
Modality principle	narration and visual aids versus text and visual aids (parallel versus successive information acquisition)	- Parallel acquisition: supports SOI and RCs - Sequential acquisition: Hinders SOI and RCs
Coherence principle	Presence or absence of extraneous sounds, visual aids, and written or narrated text	- Presence of extraneous material: hinders SOI and RCs - Absence of extraneous material: supports SOI and RCs

SLH factors. Seufert and Brunken’s (2004, 2006) surface level help factors, which are part of the overall coherence formation theory, also provide factors that may impact SOI processes. In this dissertation, color coding was catalogues as an SLH factor. Other SLH factors are dynamic linking of information and inter-textual hyperlinks. Both factors rely on the beneficial aspect of pre-attentive processing. In this dissertation, color coding offered mixed results, depending on the temporal contiguity of the presented information. Thus, future research should investigate how other SLH factor may differentially impact SOI processes and RCs.

Table 28. *SLH factors in relation to possible manipulations and expected effect on SOI and RCs.*

SLH factors	Manipulation	Expected effect on SOI and RCs
Dynamic linking	Presence or absence of dynamic linking	- Presence: supports SOI and RCs - Absence: hinders SOI and RCs
Inter-textual hyperlinks	Presence or absence of inter-textual hyperlinks	- Presence: supports SOI and RCs - Absence: hinders SOI and RCs

RC Measures and Development

Future research investigating RCs would require a continued amelioration of the techniques used in this dissertation to appropriately and reliably measure that construct. Regarding the three techniques used in this dissertation, the development of more and less ambiguous items may help in increasing overall reliability. Furthermore, as mentioned earlier, a need to match type of sub-measures across measures would also aid in obtaining a better psychometric understanding of the RC construct. Moreover, other techniques and metrics (e.g., reaction time) could also provide unique insight into better comprehending RCs. Overall, since the notion of directly measuring underlying cognitive mechanisms is novel, future research will need to invest into refining the techniques brought forth in this dissertation in conjunction to exploring other methods.

Now that evidence exists for RCs and their relationship with learning, it is necessary to continue this process and verify other similar outcomes that are theoretically related to the process of learning, such as Paivio's (1991) representational and associative connections, which are responsible to attribute meaning to perceived information and connect information within working memory stores, respectively. Thus, this dissertation helped open an important research venue, aimed at directly investigating cognitive mechanisms. Ultimately, a comprehensive theoretical understanding of the most important working memory processes, accounting for individual predispositions, will lead to accurately diagnose cognitive learning outcomes, and refine empirically validated instructional design guidelines and principles that can be easily followed when developing multimedia instructional material.

Conclusion

This dissertation investigated the effects on manipulating temporal contiguity and color coding in a multimedia CBT paradigm. Furthermore, this dissertation sought out to better understand the role of RCs by measuring them directly and to examine their relationship with learning. It was found that (a) the interaction of temporal contiguity and color coding affected knowledge of instruments, (b) the same interaction affected the development of RCs, and that (c) RCs did mediate instruments knowledge. Theoretical implications focused on clarifying the role of RCs when learning, and practical implications centered on developing instructional design guidelines that would take into consideration individual predispositions such as verbal and spatial ability. Overall, this dissertation contributes to training theory by offering insight into the relationship between cognitive mechanisms and learning, and by providing a multimedia learning framework that can better diagnose cognitive learning outcomes. As a result, multimedia learning theory can generate more precise multimedia design guidelines to better support the learning process.

APPENDIX A:
FULL RESULTS MATRIX BY ORDER OF HYPOTHESES

Hypotheses		Statistics		Means
#	Manipulation / Statement	Type of Test / DV(s)	Values (one-tailed)	
1	<i>Temporal contiguity main effect:</i> Trainees in the simultaneous condition are hypothesized to develop significantly stronger RCs when compared to trainees in the successive condition.	MANCOVA (RC1, RC2, RC3 overall)	Not significant	N/A
		MANCOVA (RC1, RC2, RC3 surface parts)	$F(3, 88) = 2.59$, $p = .029$, $\eta^2 = .081$	N/A
		ANCOVA (RC1 surface parts)	$F(1, 90) = 5.30$, $p = .012$, $\eta^2 = .056$	Simult. ($M = .60$, $SE = .02$) Sequent. ($M = .52$, $SE = .02$)
		MANCOVA (RC1, RC3, maneuvers)	Not significant	N/A
		MANCOVA (RC1, RC3, axes of flight)	Not significant	N/A
		MANCOVA (RC1, RC3, gyroscopic instruments)	$F(2, 89) = 4.44$, $p < .001$, $\eta^2 = .091$	N/A
		ANCOVA (RC3, gyroscopic instruments)	$F(1, 90) = 5.88$, $p < .001$, $\eta^2 = .061$	Simult. ($M = .86$, $SE = .05$) Sequent. ($M = .70$, $SE = .05$)
		MANCOVA (RC1, RC3, pitot-static instruments)	Not significant	N/A
		ANCOVA (RC overall)	Not significant	N/A

Note: Green font used for statistics that are reported in the Results section

Hypotheses		Statistics		Means
#	Manipulation / Statement	Type of Test / DV(s)	Values (one-tailed)	
2A	<i>Temporal contiguity main effect:</i> Trainees in the simultaneous condition are hypothesized to perform significantly better on integrative knowledge measure when compared to trainees in the successive condition.	ANCOVA (Integrative instruments)	Not significant	N/A
		ANCOVA (Integrative maneuvers)	Not significant	N/A
2B	<i>Temporal contiguity main effect:</i> Trainees in the simultaneous condition are hypothesized to perform significantly better on declarative knowledge measure when compared to trainees in the successive condition.	ANCOVA (Declarative surface parts)	Not significant	N/A
		ANCOVA (Declarative axes of flight)	Not significant	N/A
		ANCOVA (Declarative gyroscopic instruments)	Not significant	N/A
		ANCOVA (Declarative pitot-static instruments)	Not significant	N/A
2 [†]	<i>Post Hoc hypothesis:</i> Trainees in the simultaneous condition are hypothesized to perform significantly better than trainees in the sequential condition on the overall instruments knowledge measure	ANCOVA (Instruments knowledge)	Not significant	N/A

† Hypothesis not present in Introduction

Hypotheses		Statistics		Means
#	Manipulation / Statement	Type of Test / DV(s)	Values (one-tailed)	
3A	<i>Color coding main effect:</i> Trainees in the paired color-coding condition are hypothesized to develop significantly stronger RCs when compared to trainees in the no-pairing color-coding condition.	N/A	N/A	N/A
3B	<i>Color coding main effect:</i> Trainees in the paired color-coding* condition are hypothesized to develop significantly stronger RCs when compared to the no color-coding condition. * Due to the collapsing of paired and non-paired color coding, this hypothesis refers to the color coded group.	MANCOVA (RC1, RC2, RC3 overall)	Not significant	N/A
		MANCOVA (RC1, RC2, RC3 surface parts)	Not significant	N/A
		ANCOVA (RC1 surface parts)	Not significant	N/A
		MANCOVA (RC1, RC3, maneuvers)	Not significant	N/A
		MANCOVA (RC1, RC3, axes of flight)	Not significant	N/A
		MANCOVA (RC1, RC3, gyroscopic instruments)	Not significant	N/A
		ANCOVA (RC1, gyroscopic instruments)	$F(1, 90) = 2.78, p = .050, \eta^2 = .030$	Color ($M = .82, SE = .02$) No color ($M = .75, SE = .04$)
		MANCOVA (RC1, RC3, pitot-static instruments)	Not significant	N/A
		ANCOVA (RC3, pitot-static instruments)	$F(1, 90) = 2.42, p = .062, \eta^2 = .026$	Color ($M = .65, SE = .04$) No color ($M = .53, SE = .06$)
ANCOVA (RC overall)	$F(1, 90) = 2.84, p = .048, \eta^2 = .015.$	Color ($M = .74, SE = .02$) No color ($M = .67, SE = .03$)		

Note: Green font used for statistics that are reported in the Results section

Hypotheses		Statistics		Means
#	Manipulation / Statement	Type of Test / DV(s)	Values (one-tailed)	
4A	<p><i>Color coding main effect:</i> Trainees in the paired color-coding* condition are hypothesized to perform significantly better than trainees in the no-color conditions on the integrative learning measure.</p> <p>* Due to the collapsing of paired and non-paired color coding, this hypothesis refers to the color coded group.</p>	ANCOVA (Integrative instruments)	Not significant	N/A
		ANCOVA (Integrative maneuvers)	Not significant	N/A
4B	<p><i>Color coding main effect:</i> Trainees in the paired color-coding* condition are hypothesized to perform significantly better than trainees in the no-color conditions on the declarative measure.</p> <p>* Due to the collapsing of paired and non-paired color coding, this hypothesis refers to the color coded group.</p>	ANCOVA (Declarative surface parts)	Not significant	N/A
		ANCOVA (Declarative axes of flight)	Not significant	N/A
		ANCOVA (Declarative gyroscopic instruments)	Not significant	N/A
		ANCOVA (Declarative pitot-static instruments)	Not significant	N/A
4 [†]	<p><i>Post Hoc hypothesis:</i> Trainees in the color coding condition are hypothesized to perform significantly better than trainees in the no-color conditions on the overall instruments knowledge measure</p>	ANCOVA (Instruments knowledge)	Not significant	N/A

† Hypothesis not present in Introduction

Hypotheses		Statistics		Means
#	Manipulation / Statement	Type of Test / DV(s)	Values (one-tailed)	
5A	<i>Temporal contiguity by color coding interaction:</i> Trainees in the simultaneous and paired color-coding condition should develop significantly stronger RCs when compared to trainees in the simultaneous and no-pairing color-coding condition.	N/A	N/A	N/A
5B	<i>Temporal contiguity by color coding interaction:</i> Trainees in the simultaneous and paired color-coding* condition should develop significantly stronger RCs when compared to trainees in the no color-coding condition. * Due to the collapsing of paired and non-paired color coding, this hypothesis refers to the color coded group.	MANCOVA (RC1, RC2, RC3 overall)	Not significant	N/A
		MANCOVA (RC1, RC2, RC3 surface parts)	$F(3, 88) = 2.67, p = .027, \eta^2 = .083$	N/A
		ANCOVA (RC3 surface parts)	$F(1, 90) = 7.93, p = .003, \eta^2 = .081$	Simultaneous and color ($M = .99, SE = .02$) Simultaneous and no color ($M = .89, SE = .03$) Sequential and color ($M = .95, SE = .02$) Sequential and no color ($M = .99, SE = .03$)
		MANCOVA (RC1, RC3, maneuvers)	Not significant	N/A
		MANCOVA (RC1, RC3, axes of flight)	Not significant	N/A
		MANCOVA (RC1, RC3, gyroscopic instruments)	Not significant	N/A
		MANCOVA (RC1, RC3, pitot-static instruments)	$F(2, 89) = 2.59, p = .041, \eta^2 = .055.$	N/A
		ANCOVA (RC1, pitot-static instruments)	$F(1, 90) = 3.48, p = .033, \text{partial } \eta^2 = .037$	Simultaneous and color ($M = .74, SE = .04$) Simultaneous and no color ($M = .60, SE = .06$) Sequential and color ($M = .64, SE = .04$) Sequential and no color ($M = .68, SE = .06$)
		ANCOVA (RC3, pitot-static instruments)	$F(1, 90) = 4.22, p = .022, \text{partial } \eta^2 = .045$	Simultaneous and color ($M = .69, SE = .06$) Simultaneous and no color ($M = .43, SE = .09$) Sequential and color ($M = .60, SE = .06$) Sequential and no color ($M = .64, SE = .08$)

Note: Green font used for statistics that are reported in the Results section

Hypotheses		Statistics		Means
#	Manipulation / Statement	Type of Test / DV(s)	Values (one-tailed)	
6A	<i>Temporal contiguity by color coding interaction:</i> Trainees in the simultaneous and paired color-coding condition should perform significantly better than trainees in the simultaneous and no-pairing color-coding condition on the declarative and integrative measures	N/A	N/A	N/A
6B	<i>Temporal contiguity by color coding interaction:</i> Trainees in the simultaneous and paired color-coding condition* should perform significantly better than trainees in the simultaneous and no color-coding condition on the declarative and integrative measures * Due to the collapsing of paired and non-paired color coding, this hypothesis refers to the color coded group.	ANCOVA (Declarative surface parts)	Not significant	N/A
		ANCOVA (Declarative axes of flight)	Not significant	N/A
		ANCOVA (Declarative gyroscopic instruments)	$F(1, 90) = 4.23, p = .021, \eta^2 = .045$	Simultaneous and color ($M = .83, SE = .03$) Simultaneous and no color ($M = .75, SE = .05$) Sequential and color ($M = .72, SE = .03$) Sequential and no color ($M = .82, SE = .04$)
		ANCOVA (Declarative pitot-static instruments)	Not significant	N/A
		ANCOVA (Integrative instruments)	$F(1, 90) = 3.10, p = .040, \eta^2 = .033$	Simultaneous and color ($M = .68, SE = .03$) Simultaneous and no color ($M = .58, SE = .05$) Sequential and color ($M = .63, SE = .03$) Sequential and no color ($M = .67, SE = .05$)
		ANCOVA (Integrative maneuvers)	Not significant	N/A
6 [†]	<i>Post Hoc hypothesis:</i> Trainees in the simultaneous and color coding condition are hypothesized to perform significantly better than trainees in the simultaneous and no-color conditions on the overall instruments knowledge measure	ANCOVA (Instruments knowledge)	$F(1, 90) = 4.99, p = .014, \text{partial } \eta^2 = .053$	Simultaneous and color ($M = .76, SE = .03$) Simultaneous and no color ($M = .67, SE = .04$) Sequential and color ($M = .68, SE = .03$) Sequential and no color ($M = .75, SE = .04$)

Note: Green font used for statistics that are reported in the Results section; † Hypothesis not present in Introduction

Hypotheses		Statistics		Means
#	Manipulation / Statement	Type of Test / DV(s)	Values (one-tailed)	
7A	RC correlation to learning: Significant correlation between RCs and learning for the declarative knowledge measures.	Bivariate Correlation (RC1 gyroscopic instruments with declarative, gyroscopic instruments)	$r(96) = .36, p < .01$	N/A
		Bivariate Correlation (RC1 gyroscopic instruments with declarative, pitot-static instruments)	$r(96) = .32, p < .01$	N/A
		Bivariate Correlation (RC1 pitot-static instruments with declarative, gyroscopic instruments)	$r(96) = .31, p < .01$	N/A
		Bivariate Correlation (RC1 pitot-static instruments with declarative, pitot-static instruments)	$r(96) = .25, p = .01$	N/A
		Bivariate Correlation (RC3 gyroscopic instruments with declarative, gyroscopic instruments)	$r(96) = .36, p < .01$	N/A
		Bivariate Correlation (RC3 gyroscopic instruments with declarative, pitot-static instruments)	$r(96) = .37, p < .01$	N/A
		Bivariate Correlation (RC3 pitot-static instruments with declarative, gyroscopic instruments)	$r(96) = .21, p = .04$	N/A
		Bivariate Correlation (RC3 pitot-static instruments with declarative, pitot-static instruments)	$r(96) = .26, p = .01$	N/A

Note: Green font used for statistics that are reported in the Results section

Hypotheses		Statistics		Means
#	Manipulation / Statement	Type of Test / DV(s)	Values (one-tailed)	
7B	<i>RC correlation to learning</i> : Significant correlation between RCs and learning for the integrative knowledge measures.	Bivariate Correlation (RC1 gyroscopic instruments with integrative instruments)	$r(96) = .53, p < .01$	N/A
		Bivariate Correlation (RC1 gyroscopic instruments with integrative maneuvers)	$r(96) = .52, p < .01$	N/A
		Bivariate Correlation (RC1 pitot-static instruments with integrative instruments)	$r(96) = .49, p < .01$	N/A
		Bivariate Correlation (RC1 pitot-static instruments with integrative maneuvers)	$r(96) = .36, p < .01$	N/A
		Bivariate Correlation (RC3 gyroscopic instruments with integrative instruments)	$r(96) = .45, p < .01$	N/A
		Bivariate Correlation (RC3 gyroscopic instruments with integrative maneuvers)	$r(96) = .35, p < .01$	N/A
		Bivariate Correlation (RC3 pitot-static instruments with integrative instruments)	$r(96) = .51, p < .01$	N/A
		Bivariate Correlation (RC3 pitot-static instruments with integrative maneuvers)	$r(96) = .47, p < .01$	N/A

Note: Green font used for statistics that are reported in the Results section

Hypotheses		Statistics		Means
#	Manipulation / Statement	Type of Test / DV(s)	Values (one-tailed)	
8	<i>Moderated Mediation:</i> The relationship of the interaction between temporal contiguity and color coding in predicting cognitive learning outcome will be mediated by RCs.	Multiple Regression Model (RC pitot-static instruments mediation with declarative gyroscopic instruments)	Adjusted $R^2 = .277$ $F = 7.054, p < .001$	N.A.
		Multiple Regression Model (RC overall mediation with declarative gyroscopic instruments)	Adjusted $R^2 = .277$ $F = 10.261, p < .001$	N.A.
		Multiple Regression Model (RC pitot-static instruments mediation with integrative instruments)	Adjusted $R^2 = .360$ $F = 9.917, p < .001$	N.A.
		Multiple Regression Model (RC overall mediation with integrative instruments)	Adjusted $R^2 = .502$ $F = 16.945, p < .001$	N.A.
		Multiple Regression Model (RC pitot-static instruments mediation with overall instruments knowledge)	Adjusted $R^2 = .383$ $F = 10.818, p < .001$	N.A.
		Multiple Regression Model (RC overall mediation with overall instruments knowledge)	Adjusted $R^2 = .566$ $F = 19.323, p < .001$	N.A.

Note: Green font used for statistics that are reported in the Results section

APPENDIX B:
POWERPOINT VBA CODE FOR SIMULTANEOUS AND SEQUENTIAL CBT
CONDITIONS

```
'SIMULTANEOUS CONDITIONS
Dim visitedAilerons As Boolean
Dim visitedRudder As Boolean
Dim visitedElevators As Boolean
Dim visitedCenterOfGravity As Boolean
Dim visitedLongitudinalAxis As Boolean
Dim visitedLateralAxis As Boolean
Dim visitedVerticalAxis As Boolean
Dim visitedGyroscopicInstruments As Boolean
Dim visitedPitotStaticInstruments As Boolean
Dim visitedAttitudeIndicator As Boolean
Dim visitedTurnCoordinator As Boolean
Dim visitedHeadingIndicator As Boolean
Dim visitedVerticalSpeedIndicator As Boolean
Dim visitedAltimeter As Boolean
Dim visitedAirSpeedIndicator As Boolean
```

```
Sub GetStarted()
    Initialize
    ActivePresentation.SlideShowWindow.View.Next
End Sub
```

```
Sub Initialize()
    HideAirplanePartsJumpButton
        visitedAilerons = False
        visitedRudder = False
        visitedElevators = False
        ActivePresentation.Slides(2).Shapes("aileron").Visible = False
        ActivePresentation.Slides(2).Shapes("rudder").Visible = False
        ActivePresentation.Slides(2).Shapes("elevators").Visible = False
    HideAxesOfFlightJumpButton
        visitedCenterOfGravity = False
        visitedLongitudinalAxis = False
        visitedLateralAxis = False
        visitedVerticalAxis = False
        ActivePresentation.Slides(13).Shapes("LongitudinalAxis").Visible = False
        ActivePresentation.Slides(13).Shapes("VerticalAxis").Visible = False
        ActivePresentation.Slides(13).Shapes("LateralAxis").Visible = False
        ActivePresentation.Slides(13).Shapes("CenterOfGravity").Visible = False
    HideFlightInstrumentsJumpButton
        visitedGyroscopicInstruments = False
        visitedPitotStaticInstruments = False
        ActivePresentation.Slides(24).Shapes("GyroscopicInstruments").Visible = False
        ActivePresentation.Slides(24).Shapes("PitotStaticInstruments").Visible = False
    HideGyroscopicInstrumentsJumpButton
        visitedAttitudeIndicator = False
```



```

visitedTurnCoordinator = False
visitedHeadingIndicator = False
ActivePresentation.Slides(25).Shapes("AttitudeIndicator").Visible = False
ActivePresentation.Slides(25).Shapes("TurnCoordinator").Visible = False
ActivePresentation.Slides(25).Shapes("HeadingIndicator").Visible = False
HidePitotStaticInstrumentsJumpButton
visitedVerticalSpeedIndicator = False
visitedAltimeter = False
visitedAirSpeedIndicator = False
ActivePresentation.Slides(41).Shapes("AirspeedIndicator").Visible = False
ActivePresentation.Slides(41).Shapes("altimeter").Visible = False
ActivePresentation.Slides(41).Shapes("VerticalSpeedIndicator").Visible = False
End Sub

Sub HideAirplanePartsJumpButton()
ActivePresentation.Slides(2).Shapes("AirplanePartsJumpButton").Visible = False
End Sub

Sub HideAxesOfFlightJumpButton()
ActivePresentation.Slides(13).Shapes("AxesOfFlightJumpButton").Visible = False
End Sub

Sub HideFlightInstrumentsJumpButton()
ActivePresentation.Slides(24).Shapes("FlightInstrumentsJumpButton").Visible = False
End Sub

Sub HideGyroscopicInstrumentsJumpButton()
ActivePresentation.Slides(25).Shapes("GyroscopicInstrumentsJumpButton2").Visible = False
End Sub
Sub HidePitotStaticInstrumentsJumpButton()
ActivePresentation.Slides(41).Shapes("PitotStaticInstrumentsJumpButton").Visible = False
End Sub

Sub ShowAirplanePartsJumpButton()
ActivePresentation.Slides(2).Shapes("AirplanePartsJumpButton").Visible = True
End Sub

Sub ShowAxesOfFlightJumpButton()
ActivePresentation.Slides(13).Shapes("AxesOfFlightJumpButton").Visible = True
End Sub

Sub ShowFlightInstrumentsJumpButton()
ActivePresentation.Slides(24).Shapes("FlightInstrumentsJumpButton").Visible = True
End Sub

Sub ShowGyroscopicInstrumentsJumpButton()

```

```
ActivePresentation.Slides(25).Shapes("GyroscopicInstrumentsJumpButton2").Visible = True
End Sub
```

```
Sub ShowPitotStaticInstrumentsJumpButton()
ActivePresentation.Slides(41).Shapes("PitotStaticInstrumentsJumpButton").Visible = True
End Sub
```

```
Sub DoWeShowAirplanePartsJumpButton()
If visitedAilerons = True And visitedRudder = True _
And visitedElevators = True Then
ShowAirplanePartsJumpButton
Else
HideAirplanePartsJumpButton
End If
End Sub
```

```
Sub DoWeShowAxesOfFlightJumpButton()
If visitedCenterOfGravity = True And visitedLongitudinalAxis = True _
And visitedLateralAxis = True And visitedVerticalAxis = True Then
ShowAxesOfFlightJumpButton
Else
HideAxesOfFlightJumpButton
End If
End Sub
```

```
Sub DoWeShowFlightInstrumentsJumpButton()
If visitedGyroscopicInstruments = True And visitedPitotStaticInstruments = True _
Then
ShowFlightInstrumentsJumpButton
Else
HideFlightInstrumentsJumpButton
End If
End Sub
```

```
Sub DoWeShowGyroscopicInstrumentsJumpButton()
If visitedAttitudeIndicator = True And visitedTurnCoordinator = True _
And visitedHeadingIndicator = True Then
ShowGyroscopicInstrumentsJumpButton
Else
HideGyroscopicInstrumentsJumpButton
End If
End Sub
```

```
Sub DoWeShowPitotStaticInstrumentsJumpButton()
If visitedVerticalSpeedIndicator = True And visitedAltimeter = True _
And visitedAirSpeedIndicator = True Then
```

```

        ShowPitotStaticInstrumentsJumpButton
    Else
        HidePitotStaticInstrumentsJumpButton
    End If
End Sub

Sub ReturnToMenuFromAilerons()
    visitedAilerons = True
    ActivePresentation.Slides(2).Shapes("ailerons").Visible = True
    JumpToAirplaneMovingPartsMenu
End Sub

Sub ReturnToMenuFromRuddder()
    visitedRudder = True
    ActivePresentation.Slides(2).Shapes("rudder").Visible = True
    JumpToAirplaneMovingPartsMenu
End Sub

Sub ReturnToMenuFromElevators()
    visitedElevators = True
    ActivePresentation.Slides(2).Shapes("elevators").Visible = True
    JumpToAirplaneMovingPartsMenu
End Sub
Sub ReturnToMenuFromCenterOfGravity()
    visitedCenterOfGravity = True
    ActivePresentation.Slides(13).Shapes("CenterOfGravity").Visible = True
    JumpToAxesOfFlightMenu
End Sub

Sub ReturnToMenuFromLongitudinalAxis()
    visitedLongitudinalAxis = True
    ActivePresentation.Slides(13).Shapes("LongitudinalAxis").Visible = True
    JumpToAxesOfFlightMenu
End Sub

Sub ReturnToMenuFromLateralAxis()
    visitedLateralAxis = True
    ActivePresentation.Slides(13).Shapes("LateralAxis").Visible = True
    JumpToAxesOfFlightMenu
End Sub

Sub ReturnToMenuFromVerticalAxis()
    visitedVerticalAxis = True
    ActivePresentation.Slides(13).Shapes("VerticalAxis").Visible = True
    JumpToAxesOfFlightMenu
End Sub

```

```
Sub ReturnToMenuFromGyroscopicInstruments()  
    visitedGyroscopicInstruments = True  
    ActivePresentation.Slides(24).Shapes("GyroscopicInstruments").Visible = True  
    JumpToFlightInstrumentsMenu  
End Sub
```

```
Sub ReturnToMenuFromPitotStaticInstruments()  
    visitedPitotStaticInstruments = True  
    ActivePresentation.Slides(24).Shapes("PitotStaticInstruments").Visible = True  
    JumpToFlightInstrumentsMenu  
End Sub
```

```
Sub ReturnToMenuFromAttitudeIndicator()  
    visitedAttitudeIndicator = True  
    ActivePresentation.Slides(25).Shapes("AttitudeIndicator").Visible = True  
    JumpToGyroscopicInstrumentsMenu  
End Sub
```

```
Sub ReturnToMenuFromTurnCoordinator()  
    visitedTurnCoordinator = True  
    ActivePresentation.Slides(25).Shapes("TurnCoordinator").Visible = True  
    JumpToGyroscopicInstrumentsMenu  
End Sub
```

```
Sub ReturnToMenuFromHeadingIndicator()  
    visitedHeadingIndicator = True  
    ActivePresentation.Slides(25).Shapes("HeadingIndicator").Visible = True  
    JumpToGyroscopicInstrumentsMenu  
End Sub
```

```
Sub ReturnToMenuFromVerticalSpeedIndicator()  
    visitedVerticalSpeedIndicator = True  
    ActivePresentation.Slides(41).Shapes("VerticalSpeedIndicator").Visible = True  
    JumpToPitotStaticInstrumentsMenu  
End Sub
```

```
Sub ReturnToMenuFromAltimeter()  
    visitedAltimeter = True  
    ActivePresentation.Slides(41).Shapes("altimeter").Visible = True  
    JumpToPitotStaticInstrumentsMenu  
End Sub
```

```
Sub ReturnToMenuFromAirSpeedIndicator()  
    visitedAirSpeedIndicator = True  
    ActivePresentation.Slides(41).Shapes("AirspeedIndicator").Visible = True  
    JumpToPitotStaticInstrumentsMenu
```

End Sub

```
Sub JumpToAirplaneMovingPartsMenu()  
    DoWeShowAirplanePartsJumpButton  
    ActivePresentation.SlideShowWindow.View.GotoSlide (2)  
End Sub
```

```
Sub JumpToAxesOfFlightMenu()  
    DoWeShowAxesOfFlightJumpButton  
    ActivePresentation.SlideShowWindow.View.GotoSlide (13)  
End Sub
```

```
Sub JumpToFlightInstrumentsMenu()  
    DoWeShowFlightInstrumentsJumpButton  
    ActivePresentation.SlideShowWindow.View.GotoSlide (24)  
End Sub
```

```
Sub JumpToGyroscopicInstrumentsMenu()  
    DoWeShowGyroscopicInstrumentsJumpButton  
    ActivePresentation.SlideShowWindow.View.GotoSlide (25)  
End Sub
```

```
Sub JumpToPitotStaticInstrumentsMenu()  
    DoWeShowPitotStaticInstrumentsJumpButton  
    ActivePresentation.SlideShowWindow.View.GotoSlide (41)  
End Sub
```

```
Sub CloseTraining()  
    Initialize  
    ActivePresentation.Close  
End Sub
```

‘SEQUENTIAL CONDITIONS

Dim visitedAilerons As Boolean
Dim visitedRudder As Boolean
Dim visitedElevators As Boolean
Dim visitedCenterOfGravity As Boolean
Dim visitedLongitudinalAxis As Boolean
Dim visitedLateralAxis As Boolean
Dim visitedVerticalAxis As Boolean
Dim visitedGyroscopicInstruments As Boolean
Dim visitedPitotStaticInstruments As Boolean
Dim visitedAttitudeIndicator As Boolean
Dim visitedTurnCoordinator As Boolean
Dim visitedHeadingIndicator As Boolean
Dim visitedVerticalSpeedIndicator As Boolean
Dim visitedAltimeter As Boolean
Dim visitedAirSpeedIndicator As Boolean

Sub GetStarted()

 Initialize

 ActivePresentation.SlideShowWindow.View.Next

End Sub

Sub Initialize()

 HideAirplanePartsJumpButton

 visitedAilerons = False

 visitedRudder = False

 visitedElevators = False

 ActivePresentation.Slides(2).Shapes("aileron").Visible = False

 ActivePresentation.Slides(2).Shapes("rudder").Visible = False

 ActivePresentation.Slides(2).Shapes("elevators").Visible = False

 HideAxesOfFlightJumpButton

 visitedCenterOfGravity = False

 visitedLongitudinalAxis = False

 visitedLateralAxis = False

 visitedVerticalAxis = False

 ActivePresentation.Slides(13).Shapes("LongitudinalAxis").Visible = False

 ActivePresentation.Slides(13).Shapes("VerticalAxis").Visible = False

 ActivePresentation.Slides(13).Shapes("LateralAxis").Visible = False

 ActivePresentation.Slides(13).Shapes("CenterOfGravity").Visible = False

 HideFlightInstrumentsJumpButton

 visitedGyroscopicInstruments = False

 visitedPitotStaticInstruments = False

 ActivePresentation.Slides(24).Shapes("GyroscopicInstruments").Visible = False

 ActivePresentation.Slides(24).Shapes("PitotStaticInstruments").Visible = False

 HideGyroscopicInstrumentsJumpButton

 visitedAttitudeIndicator = False

```

visitedTurnCoordinator = False
visitedHeadingIndicator = False
ActivePresentation.Slides(25).Shapes("AttitudeIndicator").Visible = False
ActivePresentation.Slides(25).Shapes("TurnCoordinator").Visible = False
ActivePresentation.Slides(25).Shapes("HeadingIndicator").Visible = False
HidePitotStaticInstrumentsJumpButton
visitedVerticalSpeedIndicator = False
visitedAltimeter = False
visitedAirSpeedIndicator = False
ActivePresentation.Slides(41).Shapes("AirspeedIndicator").Visible = False
ActivePresentation.Slides(41).Shapes("altimeter").Visible = False
ActivePresentation.Slides(41).Shapes("VerticalSpeedIndicator").Visible = False
End Sub

Sub HideAirplanePartsJumpButton()
ActivePresentation.Slides(2).Shapes("AirplanePartsJumpButton").Visible = False
End Sub

Sub HideAxesOfFlightJumpButton()
ActivePresentation.Slides(13).Shapes("AxesOfFlightJumpButton").Visible = False
End Sub

Sub HideFlightInstrumentsJumpButton()
ActivePresentation.Slides(24).Shapes("FlightInstrumentsJumpButton").Visible = False
End Sub

Sub HideGyroscopicInstrumentsJumpButton()
ActivePresentation.Slides(25).Shapes("GyroscopicInstrumentsJumpButton2").Visible = False
End Sub

Sub HidePitotStaticInstrumentsJumpButton()
ActivePresentation.Slides(41).Shapes("PitotStaticInstrumentsJumpButton").Visible = False
End Sub

Sub ShowAirplanePartsJumpButton()
ActivePresentation.Slides(2).Shapes("AirplanePartsJumpButton").Visible = True
End Sub

Sub ShowAxesOfFlightJumpButton()
ActivePresentation.Slides(13).Shapes("AxesOfFlightJumpButton").Visible = True
End Sub

Sub ShowFlightInstrumentsJumpButton()
ActivePresentation.Slides(24).Shapes("FlightInstrumentsJumpButton").Visible = True
End Sub

```

```
Sub ShowGyroscopicInstrumentsJumpButton()  
    ActivePresentation.Slides(25).Shapes("GyroscopicInstrumentsJumpButton2").Visible = True  
End Sub
```

```
Sub ShowPitotStaticInstrumentsJumpButton()  
    ActivePresentation.Slides(41).Shapes("PitotStaticInstrumentsJumpButton").Visible = True  
End Sub
```

```
Sub DoWeShowAirplanePartsJumpButton()  
    If visitedAilerons = True And visitedRudder = True _  
        And visitedElevators = True Then  
        ShowAirplanePartsJumpButton  
    Else  
        HideAirplanePartsJumpButton  
    End If  
End Sub
```

```
Sub DoWeShowAxesOfFlightJumpButton()  
    If visitedCenterOfGravity = True And visitedLongitudinalAxis = True _  
        And visitedLateralAxis = True And visitedVerticalAxis = True Then  
        ShowAxesOfFlightJumpButton  
    Else  
        HideAxesOfFlightJumpButton  
    End If  
End Sub
```

```
Sub DoWeShowFlightInstrumentsJumpButton()  
    If visitedGyroscopicInstruments = True And visitedPitotStaticInstruments = True _  
        Then  
        ShowFlightInstrumentsJumpButton  
    Else  
        HideFlightInstrumentsJumpButton  
    End If  
End Sub
```

```
Sub DoWeShowGyroscopicInstrumentsJumpButton()  
    If visitedAttitudeIndicator = True And visitedTurnCoordinator = True _  
        And visitedHeadingIndicator = True Then  
        ShowGyroscopicInstrumentsJumpButton  
    Else  
        HideGyroscopicInstrumentsJumpButton  
    End If  
End Sub
```

```
Sub DoWeShowPitotStaticInstrumentsJumpButton()  
    If visitedVerticalSpeedIndicator = True And visitedAltimeter = True _
```



```

        And visitedAirSpeedIndicator = True Then
            ShowPitotStaticInstrumentsJumpButton
        Else
            HidePitotStaticInstrumentsJumpButton
        End If
    End Sub

Sub ReturnToMenuFromAilerons()
    visitedAilerons = True
    ActivePresentation.Slides(2).Shapes("aileron").Visible = True
    JumpToAirplaneMovingPartsMenu
End Sub

Sub ReturnToMenuFromRudder()
    visitedRudder = True
    ActivePresentation.Slides(2).Shapes("rudder").Visible = True
    JumpToAirplaneMovingPartsMenu
End Sub

Sub ReturnToMenuFromElevators()
    visitedElevators = True
    ActivePresentation.Slides(2).Shapes("elevators").Visible = True
    JumpToAirplaneMovingPartsMenu
End Sub

Sub ReturnToMenuFromCenterOfGravity()
    visitedCenterOfGravity = True
    ActivePresentation.Slides(13).Shapes("CenterOfGravity").Visible = True
    JumpToAxesOfFlightMenu
End Sub

Sub ReturnToMenuFromLongitudinalAxis()
    visitedLongitudinalAxis = True
    ActivePresentation.Slides(13).Shapes("LongitudinalAxis").Visible = True
    JumpToAxesOfFlightMenu
End Sub

Sub ReturnToMenuFromLateralAxis()
    visitedLateralAxis = True
    ActivePresentation.Slides(13).Shapes("LateralAxis").Visible = True
    JumpToAxesOfFlightMenu
End Sub

Sub ReturnToMenuFromVerticalAxis()
    visitedVerticalAxis = True
    ActivePresentation.Slides(13).Shapes("VerticalAxis").Visible = True

```

```
JumpToAxesOfFlightMenu
End Sub
```

```
Sub ReturnToMenuFromGyroscopicInstruments()
    visitedGyroscopicInstruments = True
    ActivePresentation.Slides(24).Shapes("GyroscopicInstruments").Visible = True
    JumpToFlightInstrumentsMenu
End Sub
```

```
Sub ReturnToMenuFromPitotStaticInstruments()
    visitedPitotStaticInstruments = True
    ActivePresentation.Slides(24).Shapes("PitotStaticInstruments").Visible = True
    JumpToFlightInstrumentsMenu
End Sub
```

```
Sub ReturnToMenuFromAttitudeIndicator()
    visitedAttitudeIndicator = True
    ActivePresentation.Slides(25).Shapes("AttitudeIndicator").Visible = True
    JumpToGyroscopicInstrumentsMenu
End Sub
```

```
Sub ReturnToMenuFromTurnCoordinator()
    visitedTurnCoordinator = True
    ActivePresentation.Slides(25).Shapes("TurnCoordinator").Visible = True
    JumpToGyroscopicInstrumentsMenu
End Sub
```

```
Sub ReturnToMenuFromHeadingIndicator()
    visitedHeadingIndicator = True
    ActivePresentation.Slides(25).Shapes("HeadingIndicator").Visible = True
    JumpToGyroscopicInstrumentsMenu
End Sub
```

```
Sub ReturnToMenuFromVerticalSpeedIndicator()
    visitedVerticalSpeedIndicator = True
    ActivePresentation.Slides(41).Shapes("VerticalSpeedIndicator").Visible = True
    JumpToPitotStaticInstrumentsMenu
End Sub
```

```
Sub ReturnToMenuFromAltimeter()
    visitedAltimeter = True
    ActivePresentation.Slides(41).Shapes("altimeter").Visible = True
    JumpToPitotStaticInstrumentsMenu
End Sub
```

```
Sub ReturnToMenuFromAirSpeedIndicator()
```

```
visitedAirSpeedIndicator = True
ActivePresentation.Slides(41).Shapes("AirspeedIndicator").Visible = True
JumpToPitotStaticInstrumentsMenu
End Sub
```

```
Sub JumpToAirplaneMovingPartsMenu()
    DoWeShowAirplanePartsJumpButton
    ActivePresentation.SlideShowWindow.View.GotoSlide (2)
End Sub
```

```
Sub JumpToAxesOfFlightMenu()
    DoWeShowAxesOfFlightJumpButton
    ActivePresentation.SlideShowWindow.View.GotoSlide (13)
End Sub
```

```
Sub JumpToFlightInstrumentsMenu()
    DoWeShowFlightInstrumentsJumpButton
    ActivePresentation.SlideShowWindow.View.GotoSlide (24)
End Sub
```

```
Sub JumpToGyroscopicInstrumentsMenu()
    DoWeShowGyroscopicInstrumentsJumpButton
    ActivePresentation.SlideShowWindow.View.GotoSlide (25)
End Sub
```

```
Sub JumpToPitotStaticInstrumentsMenu()
    DoWeShowPitotStaticInstrumentsJumpButton
    ActivePresentation.SlideShowWindow.View.GotoSlide (41)
End Sub
```

```
Sub CloseTraining()
    Initialize
    ActivePresentation.Close
End Sub
```

APPENDIX C:
COMPUTER-BASED TRAINING SLIDES TITLED ACCORDING TO THE CBT
VARIATION

Principles of Flight Training Tutorial



- This training tutorial will teach you concepts related to the principles of flight
- You are free to learn these concepts at your own pace, as there is no time limit
- Please review the information below explaining how to navigate this tutorial
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Concept

Click underlined concepts to access learning content



Click on the arrow buttons on the top-right portion of the screen to go back and forth in this tutorial



Click the "return to menu" button located next to the arrows to go back to the concepts menu



A checkmark will appear next to the links that you have accessed

Airplane Moving Parts



This section teaches you about the three main control surfaces an airplane uses to steer. Please make sure to cover all three links below to access specific information about each concept.



Ailerons



Rudder



Elevators

The Rudder (1 of 4)



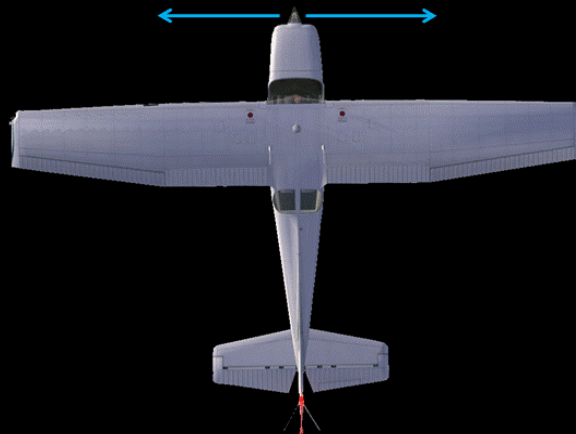
The **rudder** is attached to the back of the **vertical stabilizer**, located on the top of the airplane's tail.



The Rudder (2 of 4)



Pilots use the **rudder** to move the nose of the airplane left and right. This is known as **yaw** movement.



The Rudder (3 of 4)



When the **rudder** moves **left**, the nose of the airplane moves **left**, and when the **rudder** moves **right**, the airplane's nose moves **right**.



The Rudder (4 of 4)



The **rudder** is used in combination with the **ailerons** to initiate a **turn**.



The Ailerons (1 of 3)



The **ailerons** extend from about the midpoint of each wing outward to the tip.



The Ailerons (2 of 3)



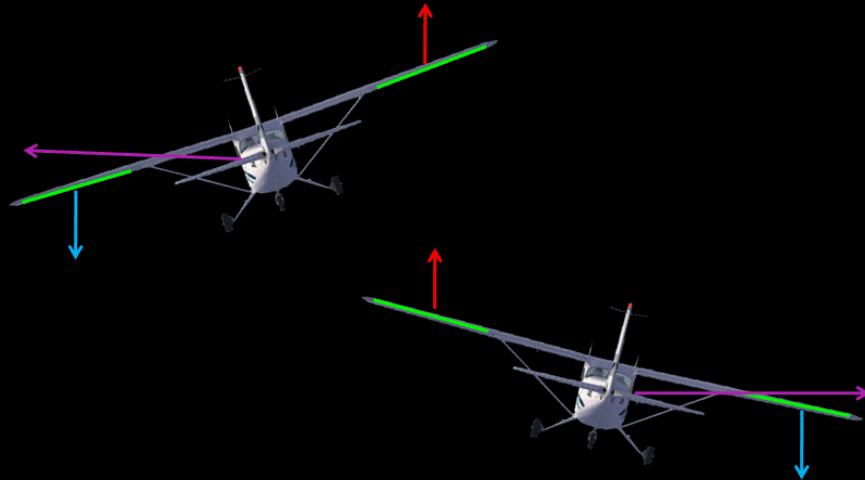
The **ailerons** move in opposite directions – when one aileron goes **up**, the other goes **down**.



The Ailerons (3 of 3)



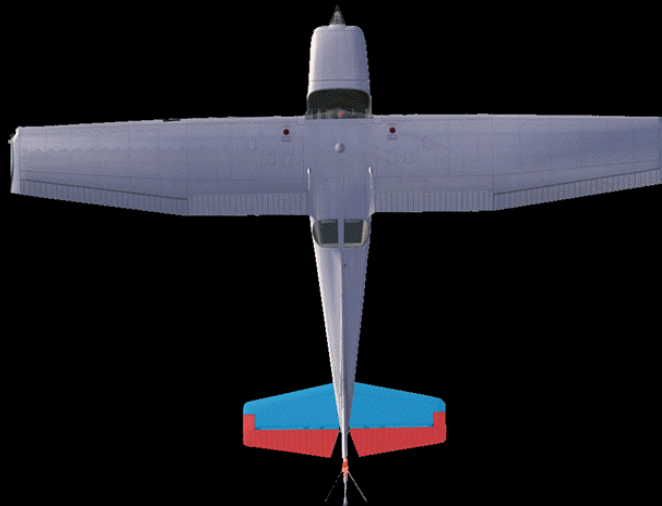
Pilots use the **aileron**s to **raise** one wing and **lower** the other in order to initiate a turn. This is known as either right or left **bank** movement



The Elevators (1 of 3)



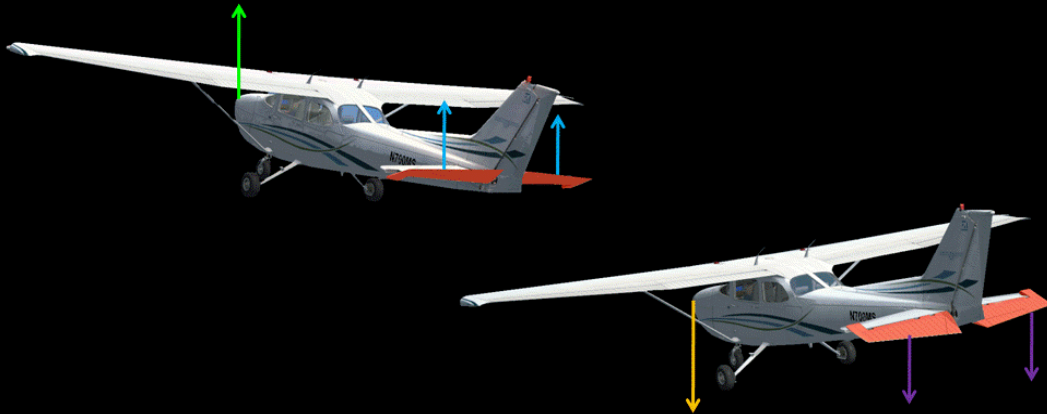
The **elevator**s are attached to the back of the **horizontal stabilizer** on the tail of the airplane.



The Elevators (2 of 3)



The **elevators** move in the same direction. When they move **up**, the nose of the plane moves up to **climb**, and when they move **down**, the nose of the plane goes down to **descend**.



The Elevators (3 of 3)



Pilots use the **elevators** to direct the airplane to the desired altitude, or height. This movement is also known as **pitch**.



Axes of Flight



This sections teaches you about the three main axes around which an airplane moves. Please follow every link to access specific information about each moving part.

The common reference point for the three axes is the airplane's center of gravity.



Longitudinal Axis



Vertical Axis

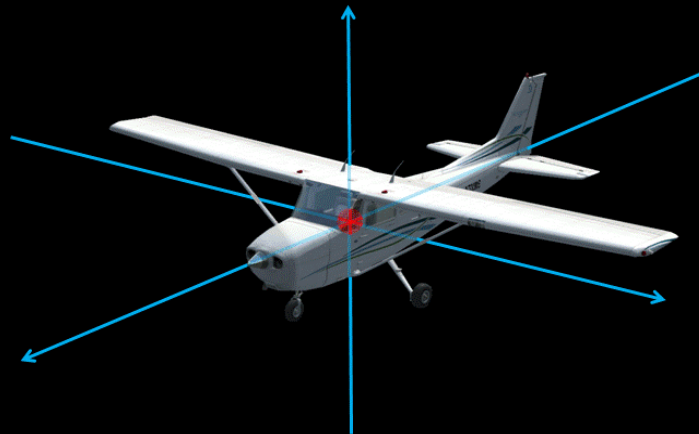


Lateral Axis

The Center of Gravity (1 of 1)



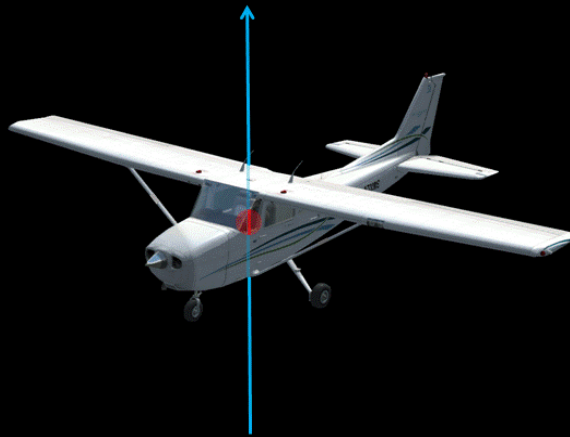
The **center of gravity** meets where the **three axes of flight** intersect. It is the theoretical point where the entire weight of the airplane is considered to be concentrated.



The Vertical Axis (1 of 3)



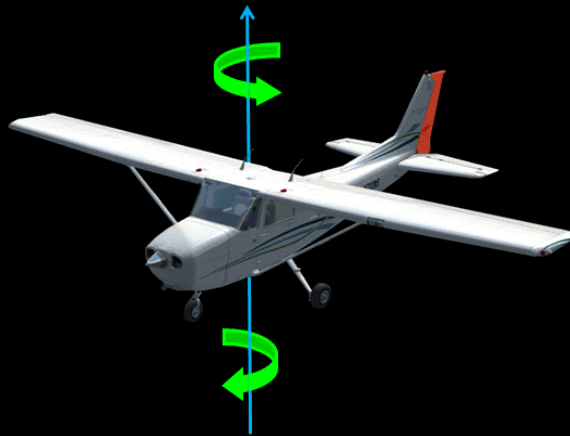
The **vertical axis** is an imaginary line that runs perpendicular to the wings through the **center of gravity**.



The Vertical Axis (2 of 3)



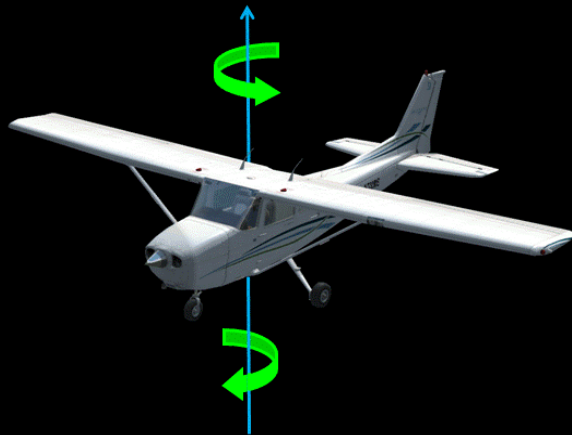
Movement around the **vertical axis** is performed using the **rudder**.



The Vertical Axis (3 of 3)



Yaw movement moves the airplane's nose left and right around the vertical axis



The Longitudinal Axis (1 of 3)



The longitudinal axis is a line that runs from the nose to the tail of the plane through the center of gravity.



The Longitudinal Axis (2 of 3)



Movement around the longitudinal axis is performed using the ailerons



The Longitudinal Axis (3 of 3)



Rotating around the longitudinal axis makes the plane roll, which is also called bank movement



The Lateral Axis (1 of 3)



The **lateral axis** that runs parallel to the wings from one wingtip to the other through the **center of gravity**.



The Lateral Axis (2 of 3)



Movement around the **lateral axis** is performed using the **elevators**



The Lateral Axis (3 of 3)



Rotating around the **lateral axis** makes the plane's nose go up and down, which is also called **pitch**



Flight Instruments



In this section, we describe the six primary flight instruments used by pilots to navigate the airplane. We will discuss how changes in the airplane's movements affect the information displayed on the instrument.

The six primary instruments are divided into the two categories below. Please, learn about all the instruments in one category before proceeding to the instruments in the other category.



Gyroscopic Instruments



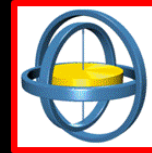
Pitot-static Instruments



Gyroscopic Instruments



A **gyroscope** is a device with, at its center, a **spinning wheel** mounted on an **axle** for measuring or maintaining orientation.



The **gyroscopic instruments** provide the pilot with a pictorial view of the airplane's attitude (top middle), rate of turn (bottom left), and heading (bottom middle).



Please, access the links below to learn about each instrument



[Attitude Indicator](#)



[Turn Coordinator](#)



[Heading Indicator](#)

The Attitude Indicator (AI) – 1 of 6



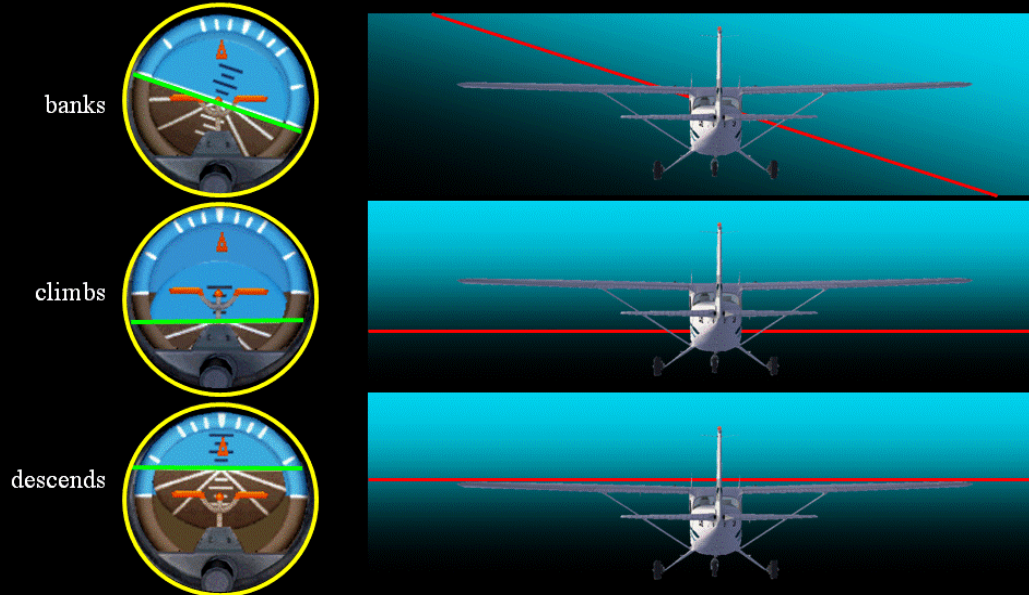
The **attitude indicator (AI)** is used as an artificial horizon when the **true horizon** is not visible. The **AI** alone can't tell you whether the airplane is maintaining level flight, climbing, or descending. It simply shows the **aircraft's attitude** relative to the **horizon**.



The Attitude Indicator (AI) – 2 of 6



The AI maintains its orientation relative to the true horizon as the airplane:



The Attitude Indicator (AI) – 3 of 6



The artificial miniature airplane at the center of the AI is used as a point of reference. The AI typically has a blue "sky" and brown "earth."



The Attitude Indicator (AI) – 4 of 6



When the plane **climbs**, the **AI** shows more **blue**



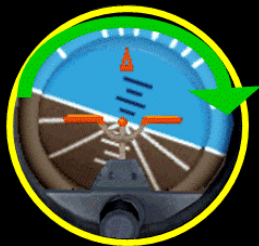
When the plane **descends**, the **AI** shows more **brown**



The Attitude Indicator (AI) – 5 of 6



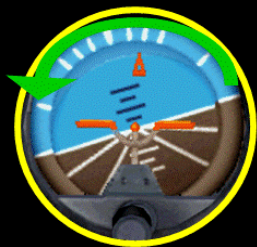
When the plane banks towards the left (moving on the **longitudinal axis**), the **AI** rotates **clockwise**.



The Attitude Indicator (AI) – 6 of 6



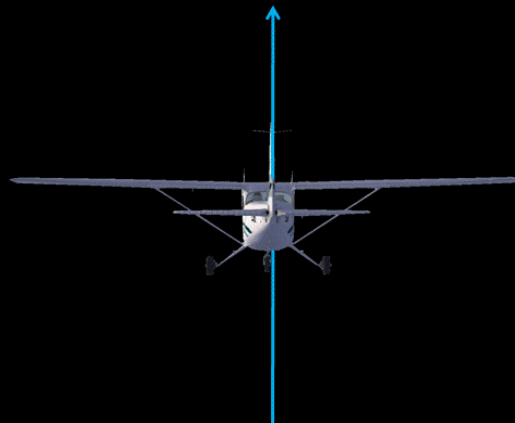
When the plane banks towards the right (moving on the longitudinal axis), the AI rotates counter-clockwise.



The Turn Coordinator (TC) – 1 of 5



The turn coordinator is used to show the aircraft's rate of turn—how fast it's changing direction. A mechanism in the turn coordinator is oriented such that when the airplane turns on the vertical axis it forces the miniature airplane on the TC to turn.



The Turn Coordinator (TC) – 2 of 5



The rate of movement makes the TC's miniature airplane lean to the left or right.



The Turn Coordinator (TC) – 3 of 5



When the wings of the miniature airplane align with the lines next to the "L" and "R," the aircraft is making a standard rate turn:



Standard rate turn to the left

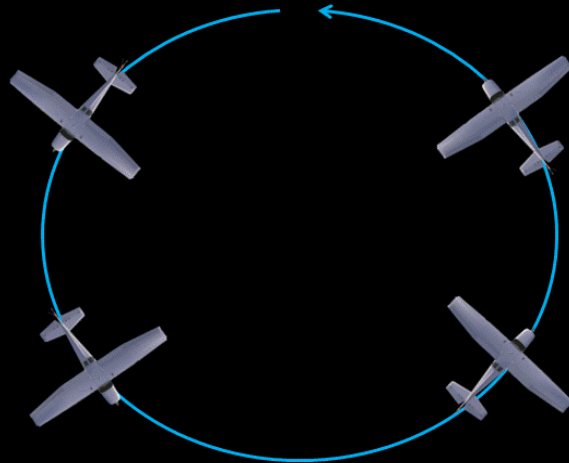


Standard rate turn to the right

The Turn Coordinator (TC) – 4 of 5



A **standard rate turn** indicates that the aircraft completes a **360-degree turn** in **two minutes**.



The Turn Coordinator (TC) – 5 of 5



The faster the turn, the greater the movement, and the steeper the lean of the **TC's miniature airplane**:



Standard rate turn
to the **left**



Steep turn to
the **right**

The Heading Indicator (HI) – 1 of 4



The heading indicator is sometimes called the “compass card.” The HI provides a smooth and precise indication of heading or turns as a result of yaw movement.



The Heading Indicator (HI) – 2 of 4



A card in the HI that is marked with heading degrees maintains its orientation as the actual airplane turns. Thus, the miniature airplane at the center of the HI always remains pointing upward, only this heading card rotates.



The Heading Indicator (HI) – 3 of 4



The card in the HI is marked off with numbers every 30 degrees and the cardinal directions indicated by N (North), S (South), E (East), W (West).



The Heading Indicator (HI) – 4 of 4



To read the numbers on the HI, simply “add” a zero. For example:



The HI is pointing to the “6,” which indicates a “60 degrees” heading



The HI is pointing to the “21,” which indicates a “210 degrees” heading

Pitot-Static Instruments



A Pitot-static system consists of a system of pressure-sensitive instruments and the means by which the appropriate pressures are obtained

The **Pitot-static instruments** provide the pilot with information regarding speed (top left), altitude (top right), and rate of climb or descent (bottom right).

Please, access the links below to learn about each instrument



[Airspeed Indicator](#)



[Altimeter](#)



[Vertical Speed Indicator](#)

The Airspeed Indicator (ASI) – 1 of 2



This **airspeed indicator** is calibrated in **knots**. The ASI is divided into color-coded arcs that define speed ranges for different phases of flight: for **use of flaps** (white), for **normal operations** (green), for smooth air operations or **caution speed** (yellow), and for maximum or “**never-exceed**” speed (red).



The Airspeed Indicator (ASI) – 2 of 2



The **ASI** displays changes in the forward movement of the airplane:



The **ASI** indicates a speed of **80 knots**



The **ASI** indicates a speed of **120 knots**

The Altimeter – 1 of 3



The **altimeter** displays changes in the **vertical movement** (up and down) of the airplane.



The Altimeter – 2 of 3



The **altimeter** usually has two pointers to indicate the airplanes' altitude. These pointers are generally arranged as follows:



A pointer with a **flared triangular tip** showing 1,000 foot intervals



A pointer with a **needle tip** showing 100 foot intervals

The Altimeter – 3 of 3



The **altimeter** is numbered 0 through 9. How to read the altitude on the example below:

First read the **flared triangular tip**. Here it rests between **2 and 3** (indicating an altitude above 2,000 feet)

Second, read the **needle tip**. Here it rests between **7 and 8** (indicating an at least 700 feet). Actually, it is $3/5^{\text{th}}$ of the way to 8, indicating 760 feet.



Finally, add the two values. Here we have $2,000 + 760$ indicating an altitude of 2,760

The Vertical Speed Indicator (VSI) – 1 of 2



The vertical speed indicator displays changes in the vertical rate of movement of the airplane when it climbs or descends, that is, how fast it goes up or down.



The Vertical Speed Indicator (VSI) – 2 of 2



The VSI is calibrated in 100 feet per minute intervals. To read the VSI, first determine if the needle lays up or down. Above “0” indicates a climb and below “0” indicates a descent, and then gauge the speed of the ascent/descent



Here the VSI shows a rate of climb of 500 feet per minute.

End of Training Tutorial



- This is the end of your training on the principles of flight
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This section teaches you about the three main control surfaces an airplane uses to steer. Please make sure to cover all three links below to access specific information about each concept.



Ailerons



Rudder



Elevators

The Rudder (1 of 4)



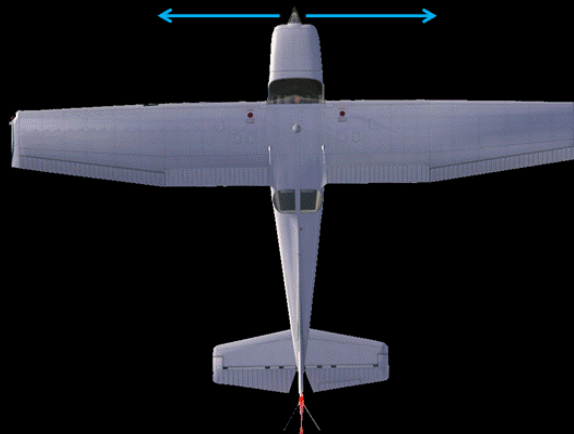
The **rudder** is attached to the back of the **vertical stabilizer**, located on the top of the airplane's tail.



The Rudder (2 of 4)



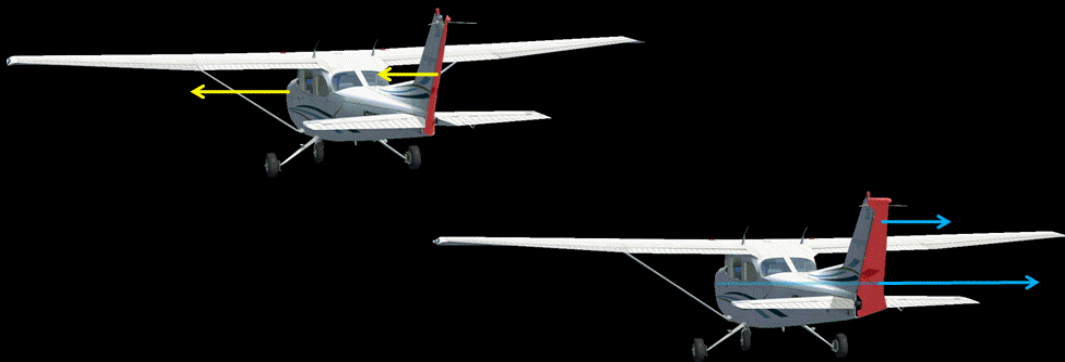
Pilots use the **rudder** to move the nose of the airplane left and right. This is known as **yaw** movement.



The Rudder (3 of 4)



When the rudder moves left, the nose of the airplane moves left, and when the rudder moves right, the airplane's nose moves right.



The Rudder (4 of 4)



The rudder is used in combination with the ailerons to initiate a turn.



The Ailerons (1 of 3)



The **aileron**s extend from about the midpoint of each wing outward to the tip.



The Ailerons (2 of 3)



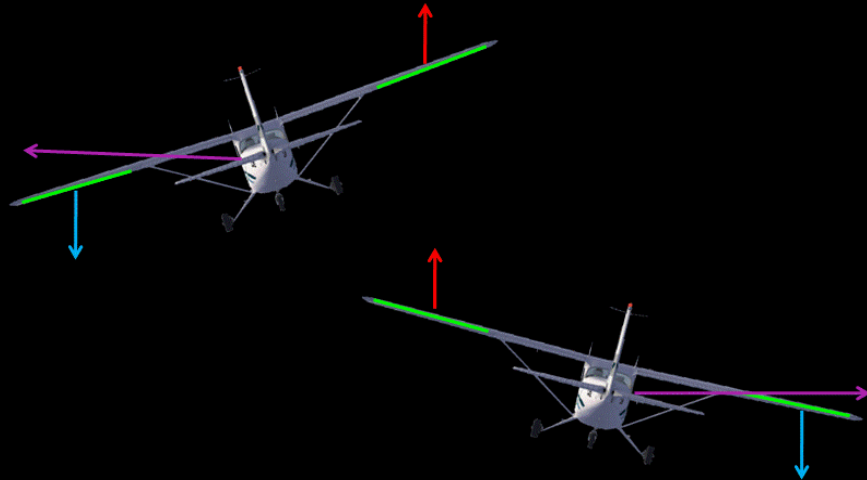
The **aileron**s move in opposite directions – when one aileron goes **up**, the other goes **down**.



The Ailerons (3 of 3)



Pilots use the **aileron**s to **raise** one wing and **lower** the other in order to initiate a turn. This is known as either right or left **bank** movement



The Elevators (1 of 3)



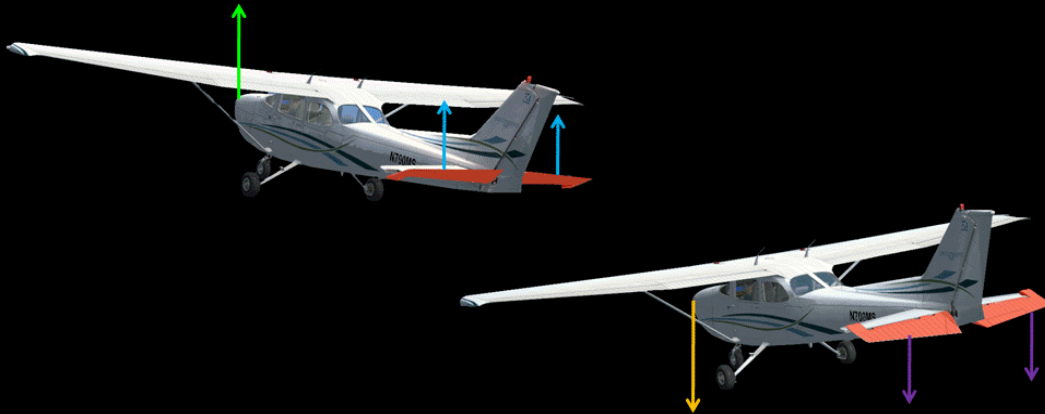
The **elevator**s are attached to the back of the **horizontal stabilizer** on the tail of the airplane.



The Elevators (2 of 3)



The **elevators** move in the same direction. When they move **up**, the nose of the plane moves up to **climb**, and when they move **down**, the nose of the plane goes down to **descend**.



The Elevators (3 of 3)



Pilots use the **elevators** to direct the airplane to the desired altitude, or height. This movement is also known as **pitch**.



Axes of Flight



This sections teaches you about the three main axes around which an airplane moves. Please follow every link to access specific information about each moving part.

The common reference point for the three axes is the airplane's [center of gravity](#).



[Longitudinal Axis](#)



[Vertical Axis](#)

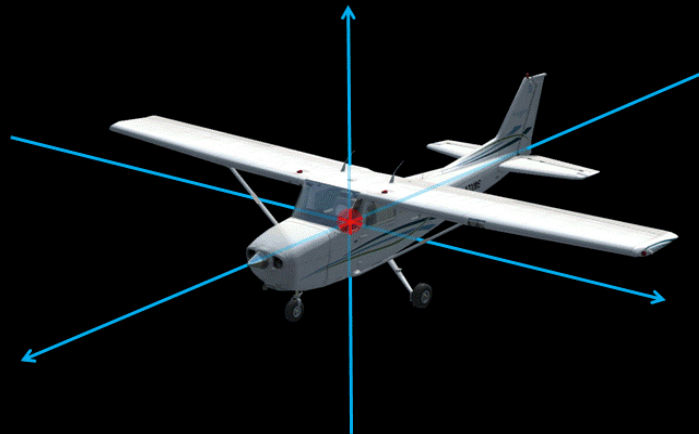


[Lateral Axis](#)

The Center of Gravity (1 of 1)



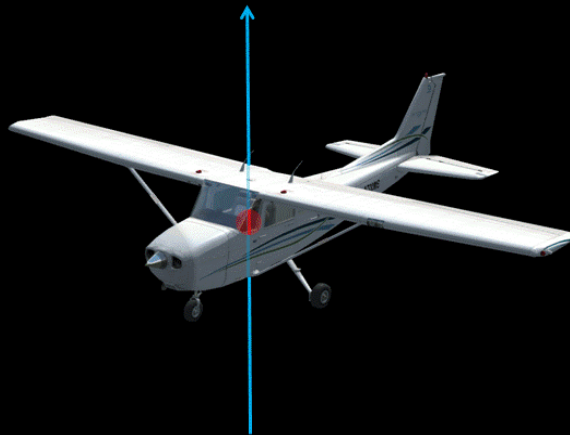
The [center of gravity](#) meets where the [three axes of flight](#) intersect. It is the theoretical point where the entire weight of the airplane is considered to be concentrated.



The Vertical Axis (1 of 3)



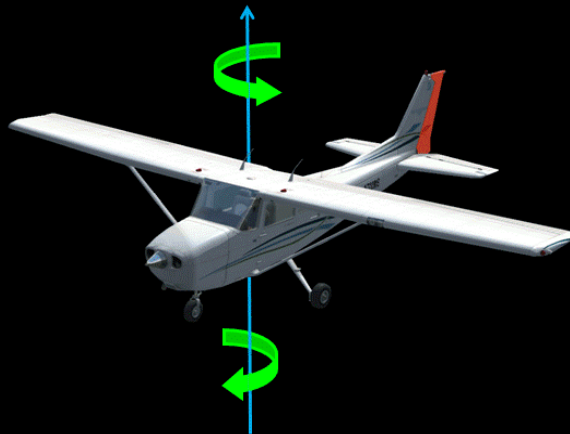
The **vertical axis** is an imaginary line that runs perpendicular to the wings through the **center of gravity**.



The Vertical Axis (2 of 3)



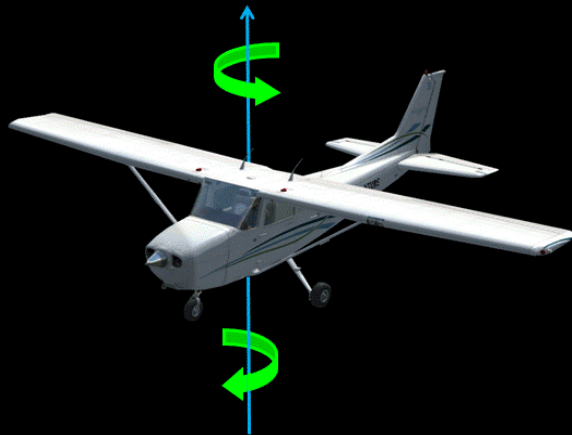
Movement around the **vertical axis** is performed using the **rudder**



The Vertical Axis (3 of 3)



Yaw movement moves the airplane's nose left and right around the vertical axis



The Longitudinal Axis (1 of 3)



The longitudinal axis is a line that runs from the nose to the tail of the plane through the center of gravity.



The Longitudinal Axis (2 of 3)



Movement around the longitudinal axis is performed using the ailerons



The Longitudinal Axis (3 of 3)



Rotating around the longitudinal axis makes the plane roll, which is also called bank movement



The Lateral Axis (1 of 3)



The **lateral axis** that runs parallel to the wings from one wingtip to the other through the **center of gravity**.



The Lateral Axis (2 of 3)



Movement around the **lateral axis** is performed using the **elevators**



The Lateral Axis (3 of 3)



Rotating around the **lateral axis** makes the plane's nose go up and down, which is also called **pitch**



Flight Instruments



In this section, we describe the six primary flight instruments used by pilots to navigate the airplane. We will discuss how changes in the airplane's movements affect the information displayed on the instrument.

The six primary instruments are divided into the two categories below. Please, learn about all the instruments in one category before proceeding to the instruments in the other category.



Gyroscopic Instruments



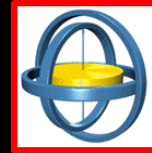
Pitot-static Instruments



Gyroscopic Instruments



A **gyroscope** is a device with, at its center, a **spinning wheel** mounted on an **axle** for measuring or maintaining orientation.



The **gyroscopic instruments** provide the pilot with a pictorial view of the airplane's attitude (top middle), rate of turn (bottom left), and heading (bottom middle).



Please, access the links below to learn about each instrument



[Attitude Indicator](#)

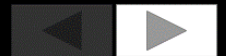


[Turn Coordinator](#)



[Heading Indicator](#)

The Attitude Indicator (AI) – 1 of 6



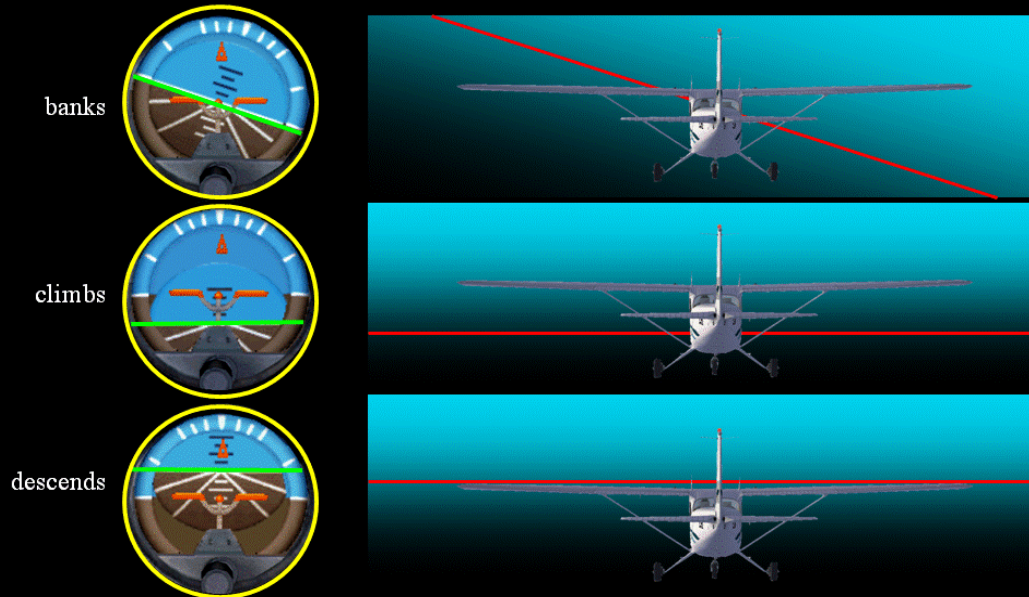
The **attitude indicator (AI)** is used as an artificial horizon when the **true horizon** is not visible. The **AI** alone can't tell you whether the airplane is maintaining level flight, climbing, or descending. It simply shows the **aircraft's attitude** relative to the **horizon**.



The Attitude Indicator (AI) – 2 of 6



The AI maintains its orientation relative to the true horizon as the airplane:



The Attitude Indicator (AI) – 3 of 6



The artificial miniature airplane at the center of the AI is used as a point of reference. The AI typically has a blue "sky" and brown "earth."



The Attitude Indicator (AI) – 4 of 6



When the plane **climbs**, the AI shows more **blue**



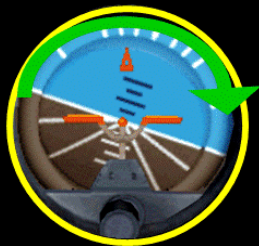
When the plane **descends**, the AI shows more **brown**



The Attitude Indicator (AI) – 5 of 6



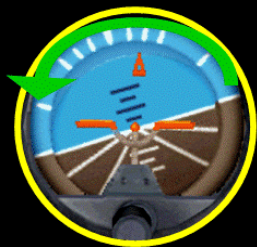
When the plane banks towards the left (moving on the **longitudinal axis**), the AI rotates **clockwise**.



The Attitude Indicator (AI) – 6 of 6



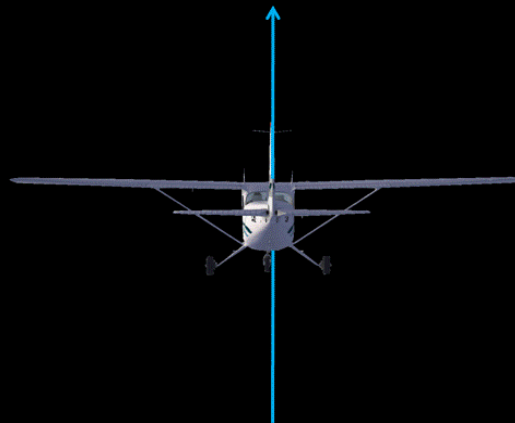
When the plane banks towards the right (moving on the longitudinal axis), the AI rotates counter-clockwise.



The Turn Coordinator (TC) – 1 of 5



The turn coordinator is used to show the aircraft's rate of turn—how fast it's changing direction. A mechanism in the turn coordinator is oriented such that when the airplane turns on the vertical axis it forces the miniature airplane on the TC to turn.



The Turn Coordinator (TC) – 2 of 5



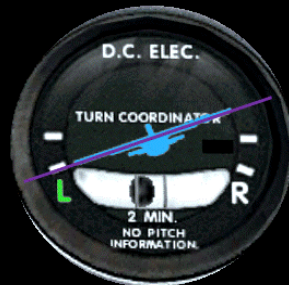
The rate of movement makes the TC's miniature airplane lean to the left or right.



The Turn Coordinator (TC) – 3 of 5



When the wings of the miniature airplane align with the lines next to the "L" and "R," the aircraft is making a standard rate turn:



Standard rate turn to the left

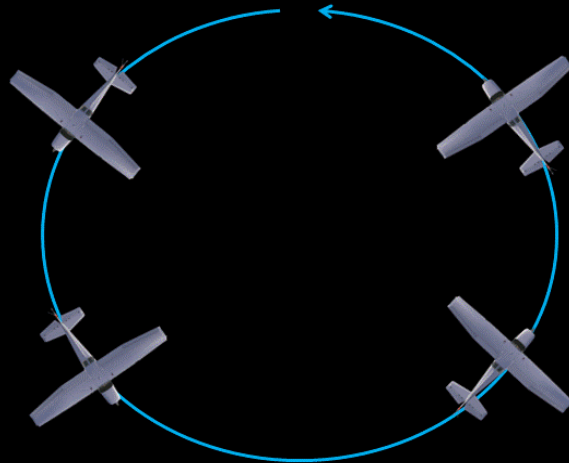


Standard rate turn to the right

The Turn Coordinator (TC) – 4 of 5



A **standard rate turn** indicates that the aircraft completes a **360-degree turn** in **two minutes**.



The Turn Coordinator (TC) – 5 of 5



The faster the turn, the greater the movement, and the steeper the lean of the TC's miniature airplane:



Standard rate turn to the **left**



Steep turn to the **right**

The Heading Indicator (HI) – 1 of 4



The heading indicator is sometimes called the “compass card.” The HI provides a smooth and precise indication of heading or turns as a result of yaw movement.



The Heading Indicator (HI) – 2 of 4



A card in the HI that is marked with heading degrees maintains its orientation as the actual airplane turns. Thus, the miniature airplane at the center of the HI always remains pointing upward, only this heading card rotates.



The Heading Indicator (HI) – 3 of 4



The card in the HI is marked off with numbers every 30 degrees and the cardinal directions indicated by N (North), S (South), E (East), W (West).



The Heading Indicator (HI) – 4 of 4



To read the numbers on the HI, simply “add” a zero. For example:



The HI is pointing to the “6,” which indicates a “60 degrees” heading



The HI is pointing to the “21,” which indicates a “210 degrees” heading

Pitot-Static Instruments



A Pitot-static system consists of a system of pressure-sensitive instruments and the means by which the appropriate pressures are obtained

The [Pitot-static instruments](#) provide the pilot with information regarding speed (top left), altitude (top right), and rate of climb or descent (bottom right).

Please, access the links below to learn about each instrument



[Airspeed Indicator](#)



[Altimeter](#)



[Vertical Speed Indicator](#)

The Airspeed Indicator (ASI) – 1 of 2



This [airspeed indicator](#) is calibrated in [knots](#). The ASI is divided into color-coded arcs that define speed ranges for different phases of flight: for use of [flaps \(white\)](#), for [normal operations \(green\)](#), for smooth air operations or [caution speed \(yellow\)](#), and for maximum or “[never-exceed](#)” speed (red).



The Airspeed Indicator (ASI) – 2 of 2



The **ASI** displays changes in the forward movement of the airplane:



The **ASI** indicates a speed of **80 knots**



The **ASI** indicates a speed of **120 knots**

The Altimeter – 1 of 3



The **altimeter** displays changes in the **vertical movement** (up and down) of the airplane.



The Altimeter – 2 of 3



The **altimeter** usually has two pointers to indicate the airplanes' altitude. These pointers are generally arranged as follows:



A pointer with a **flared triangular tip** showing 1,000 foot intervals



A pointer with a **needle tip** showing 100 foot intervals

The Altimeter – 3 of 3



The **altimeter** is numbered 0 through 9. How to read the altitude on the example below:

First read the **flared triangular tip**. Here it rests between **2 and 3** (indicating an altitude above 2,000 feet)

Second, read the **needle tip**. Here it rests between **7 and 8** (indicating an at least 700 feet). Actually, it is 3/5th of the way to 8, indicating 760 feet.



Finally, add the two values. Here we have $2,000 + 760$ indicating an altitude of 2,760

The Vertical Speed Indicator (VSI) – 1 of 2



The vertical speed indicator displays changes in the vertical rate of movement of the airplane when it climbs or descends, that is, how fast it goes up or down.



The Vertical Speed Indicator (VSI) – 2 of 2



The VSI is calibrated in 100 feet per minute intervals. To read the VSI, first determine if the needle lays up or down. Above "0" indicates a climb and below "0" indicates a descent, and then gauge the speed of the ascent/descent



Here the VSI shows a rate of climb of 500 feet per minute.

End of Training Tutorial



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TUTORIAL**

Principles of Flight Training Tutorial



- This training tutorial will teach you concepts related to the principles of flight
- You are free to learn these concepts at your own pace, as there is no time limit
- Please review the information below explaining how to navigate this tutorial
- Some menus will not be accessible until all previous links are accessed
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Concept

Click underlined concepts to access learning content



Click on the arrow buttons on the top-right portion of the screen to go back and forth in this tutorial



Click the "return to menu" button located next to the arrows to go back to the concepts menu



A checkmark will appear next to the links that you have accessed

Airplane Moving Parts



This section teaches you about the three main control surfaces an airplane uses to steer. Please make sure to cover all three links below to access specific information about each concept.



Ailerons



Rudder



Elevators

The Rudder (1 of 4)



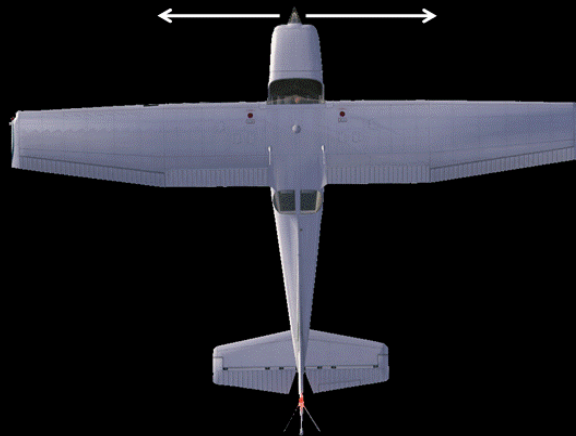
The rudder is attached to the back of the vertical stabilizer, located on the top of the airplane's tail.



The Rudder (2 of 4)



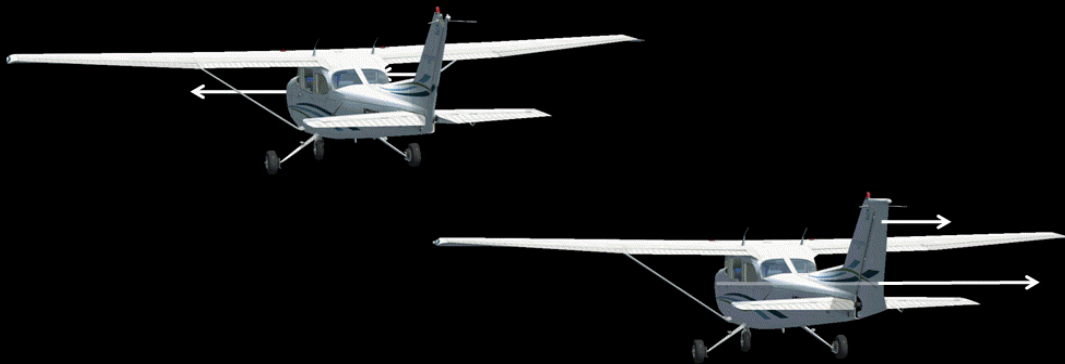
Pilots use the rudder to move the nose of the airplane left and right. This is known as yaw movement.



The Rudder (3 of 4)



When the rudder moves left, the nose of the airplane moves left, and when the rudder moves right, the airplane's nose moves right.



The Rudder (4 of 4)



The rudder is used in combination with the ailerons to initiate a turn.



The Ailerons (1 of 3)



The ailerons extend from about the midpoint of each wing outward to the tip.



The Ailerons (2 of 3)



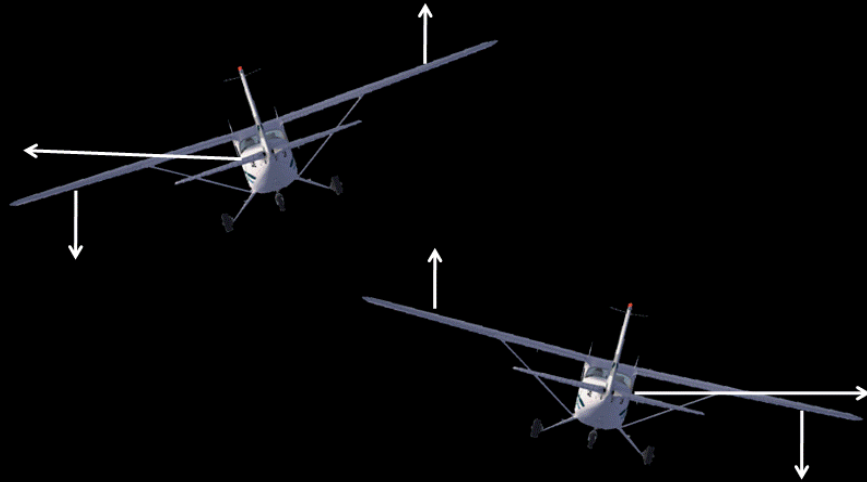
The ailerons move in opposite directions – when one aileron goes up, the other goes down.



The Ailerons (3 of 3)



Pilots use the ailerons to raise one wing and lower the other in order to initiate a turn. This is known as either right or left bank movement



The Elevators (1 of 3)



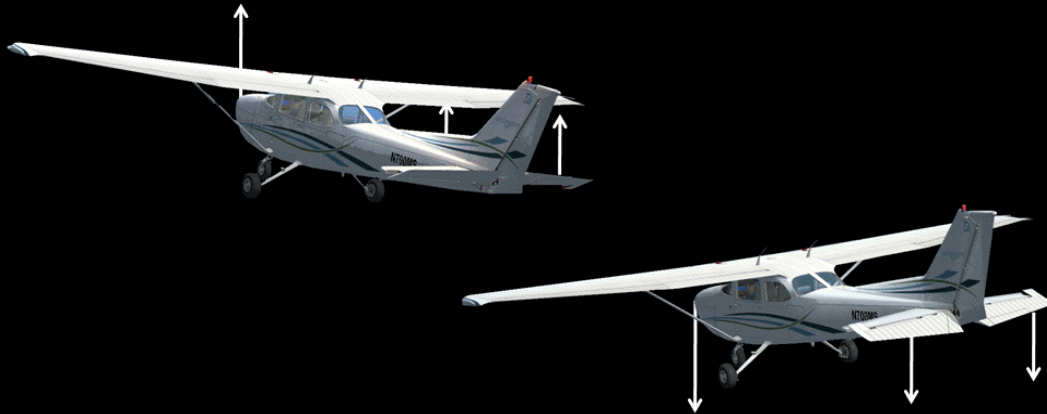
The elevators are attached to the back of the horizontal stabilizer on the tail of the airplane.



The Elevators (2 of 3)



The elevators move in the same direction. When they move up, the nose of the plane moves up to climb, and when they move down, the nose of the plane goes down to descend.



The Elevators (3 of 3)



Pilots use the elevators to direct the airplane to the desired altitude, or height. This movement is also known as pitch.



Axes of Flight



This sections teaches you about the three main axes around which an airplane moves. Please follow every link to access specific information about each moving part.

The common reference point for the three axes is the airplane's [center of gravity](#).



[Longitudinal Axis](#)



[Vertical Axis](#)

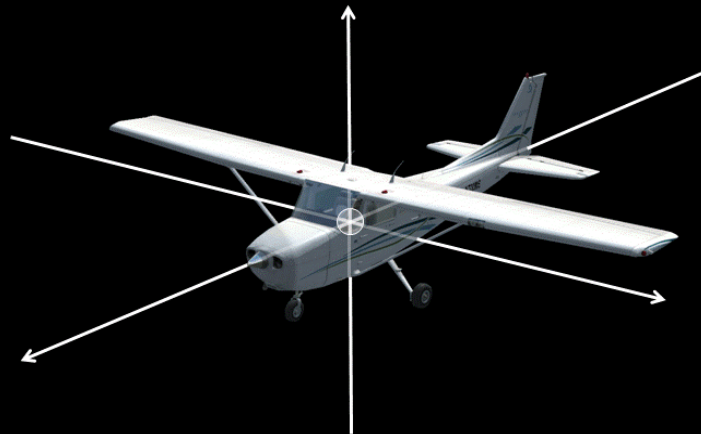


[Lateral Axis](#)

The Center of Gravity (1 of 1)



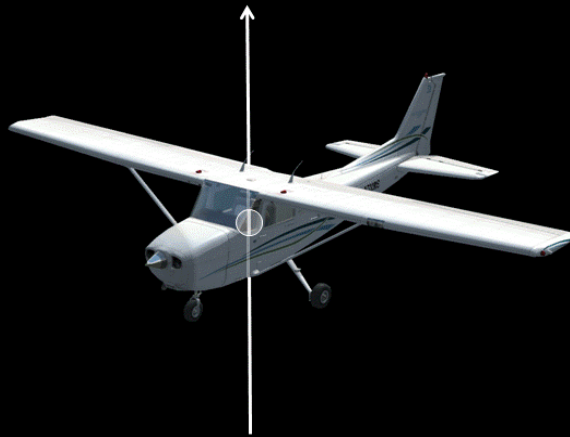
The center of gravity meets where the three axes of flight intersect. It is the theoretical point where the entire weight of the airplane is considered to be concentrated.



The Vertical Axis (1 of 3)



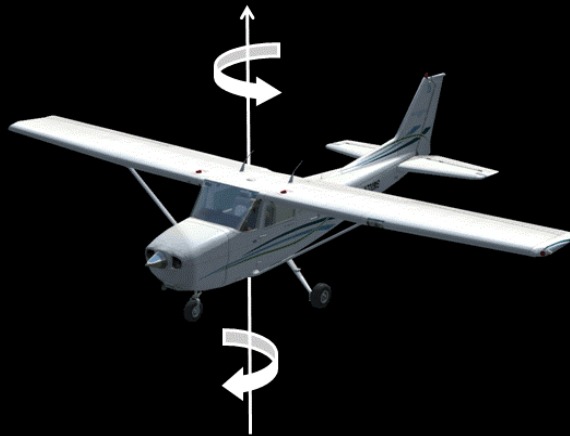
The vertical axis is an imaginary line that runs perpendicular to the wings through the center of gravity.



The Vertical Axis (2 of 3)



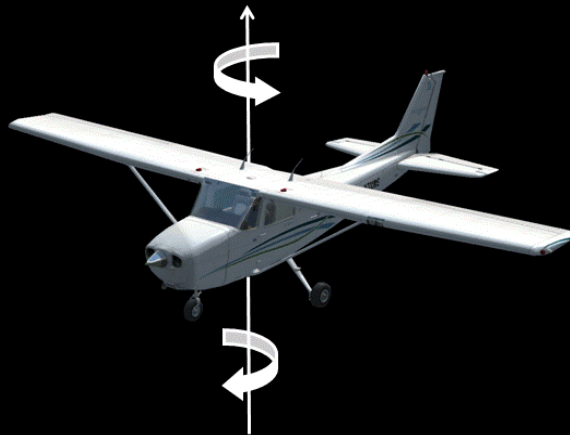
Movement around the vertical axis is performed using the rudder



The Vertical Axis (3 of 3)



Yaw movement moves the airplane's nose left and right around the vertical axis



The Longitudinal Axis (1 of 3)



The longitudinal axis is a line that runs from the nose to the tail of the plane through the center of gravity.



The Longitudinal Axis (2 of 3)



Movement around the longitudinal axis is performed using the ailerons



The Longitudinal Axis (3 of 3)



Rotating around the longitudinal axis makes the plane roll, which is also called bank movement



The Lateral Axis (1 of 3)



The lateral axis that runs parallel to the wings from one wingtip to the other through the center of gravity.



The Lateral Axis (2 of 3)



Movement around the lateral axis is performed using the elevators



The Lateral Axis (3 of 3)



Rotating around the lateral axis makes the plane's nose go up and down, which is also called pitch



Flight Instruments



In this section, we describe the six primary flight instruments used by pilots to navigate the airplane. We will discuss how changes in the airplane's movements affect the information displayed on the instrument.

The six primary instruments are divided into the two categories below. Please, learn about all the instruments in one category before proceeding to the instruments in the other category.



Gyroscopic Instruments



Pitot-static Instruments



Gyroscopic Instruments



A **gyroscope** is a device with, at its center, a spinning wheel mounted on an axle for measuring or maintaining orientation.



The gyroscopic instruments provide the pilot with a pictorial view of the airplane's attitude (top middle), rate of turn (bottom left), and heading (bottom middle).



Please, access the links below to learn about each instrument



[Attitude Indicator](#)



[Turn Coordinator](#)



[Heading Indicator](#)

The Attitude Indicator (AI) – 1 of 6



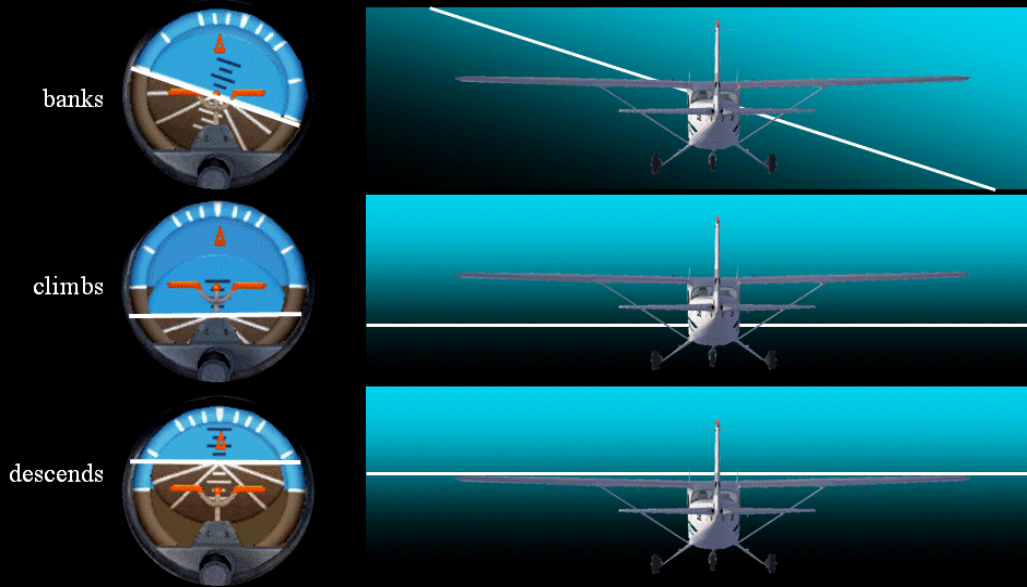
The attitude indicator (AI) is used as an artificial horizon when the true horizon is not visible. The AI alone can't tell you whether the airplane is maintaining level flight, climbing, or descending. It simply shows the aircraft's attitude relative to the horizon.



The Attitude Indicator (AI) – 2 of 6



The AI maintains its orientation relative to the true horizon as the airplane:



The Attitude Indicator (AI) – 3 of 6



The artificial miniature airplane at the center of the AI is used as a point of reference. The AI typically has a blue "sky" and brown "earth."



The Attitude Indicator (AI) – 4 of 6



When the plane climbs, the AI shows more blue



When the plane descends, the AI shows more brown



The Attitude Indicator (AI) – 5 of 6



When the plane banks towards the left (moving on the longitudinal axis), the AI rotates clockwise.



The Attitude Indicator (AI) – 6 of 6



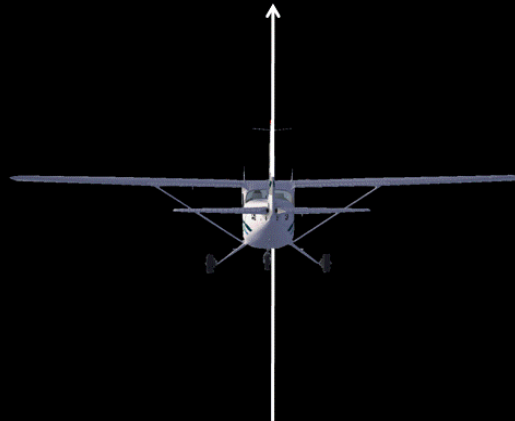
When the plane banks towards the right (moving on the longitudinal axis), the AI rotates counter-clockwise.



The Turn Coordinator (TC) – 1 of 5



The turn coordinator is used to show the aircraft's rate of turn—how fast it's changing direction. A mechanism in the turn coordinator is oriented such that when the airplane turns on the vertical axis it forces the miniature airplane on the TC to turn.



The Turn Coordinator (TC) – 2 of 5



The rate of movement makes the TC's miniature airplane lean to the left or right.



The Turn Coordinator (TC) – 3 of 5



When the wings of the miniature airplane align with the lines next to the "L" and "R," the aircraft is making a standard rate turn:



Standard rate turn
to the left

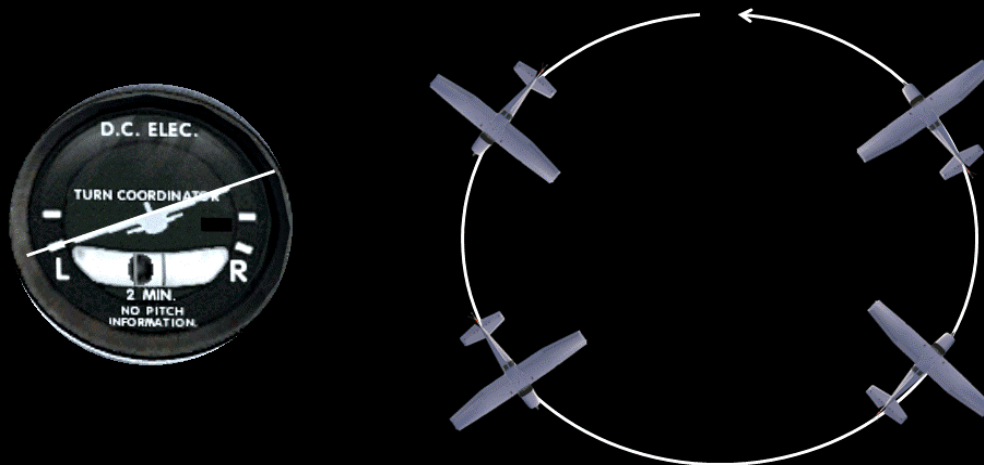


Standard rate turn
to the right

The Turn Coordinator (TC) – 4 of 5



A standard rate turn indicates that the aircraft completes a 360-degree turn in two minutes.



The Turn Coordinator (TC) – 5 of 5



The faster the turn, the greater the movement, and the steeper the lean of the TC's miniature airplane:



Standard rate turn to the left



Steep turn to the right

The Heading Indicator (HI) – 1 of 4



The heading indicator is sometimes called the “compass card.” The HI provides a smooth and precise indication of heading or turns as a result of yaw movement.



The Heading Indicator (HI) – 2 of 4



A card in the HI that is marked with heading degrees maintains its orientation as the actual airplane turns. Thus, the miniature airplane at the center of the HI always remains pointing upward, only this heading card rotates.



The Heading Indicator (HI) – 3 of 4



The card in the HI is marked off with numbers every 30 degrees and the cardinal directions indicated by N (North), S (South), E (East), W (West).



The Heading Indicator (HI) – 4 of 4



To read the numbers on the HI, simply “add” a zero. For example:



The HI is pointing to the “6,” which indicates a “60 degrees” heading



The HI is pointing to the “21,” which indicates a “210 degrees” heading

Pitot-Static Instruments



A Pitot-static system consists of a system of pressure-sensitive instruments and the means by which the appropriate pressures are obtained

The Pitot-static instruments provide the pilot with information regarding speed (top left), altitude (top right), and rate of climb or descent (bottom right).

Please, access the links below to learn about each instrument



[Airspeed Indicator](#)



[Altimeter](#)



[Vertical Speed Indicator](#)

The Airspeed Indicator (ASI) – 1 of 2



This airspeed indicator is calibrated in knots. The ASI is divided into color-coded arcs that define speed ranges for different phases of flight: for use of flaps (white), for normal operations (green), for smooth air operations or caution speed (yellow), and for maximum or “never-exceed” speed (red).



The Airspeed Indicator (ASI) – 2 of 2



The ASI displays changes in the forward movement of the airplane:



The ASI indicates a speed of 80 knots



The ASI indicates a speed of 120 knots

The Altimeter – 1 of 3



The altimeter displays changes in the vertical movement (up and down) of the airplane.



The Altimeter – 2 of 3



The altimeter usually has two pointers to indicate the airplanes' altitude. These pointers are generally arranged as follows:



A pointer with a flared triangular tip showing 1,000 foot intervals



A pointer with a needle tip showing 100 foot intervals

The Altimeter – 3 of 3



The altimeter is numbered 0 through 9. How to read the altitude on the example below:

First read the flared triangular tip. Here it rests between 2 and 3 (indicating an altitude above 2,000 feet)

Second, read the needle tip. Here it rests between 7 and 8 (indicating an at least 700 feet). Actually, it is 3/5th of the way to 8, indicating 760 feet.

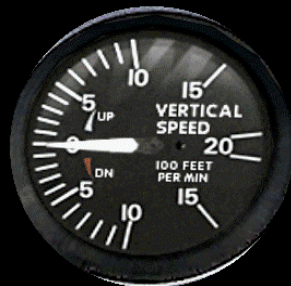


Finally, add the two values. Here we have $2,000 + 760$ indicating an altitude of 2,760

The Vertical Speed Indicator (VSI) – 1 of 2



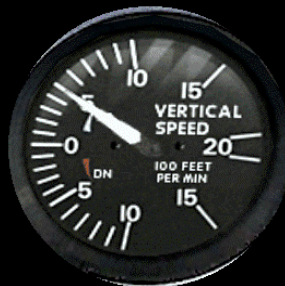
The vertical speed indicator displays changes in the vertical rate of movement of the airplane when it climbs or descends, that is, how fast it goes up or down.



The Vertical Speed Indicator (VSI) – 2 of 2



The VSI is calibrated in 100 feet per minute intervals. To read the VSI, first determine if the needle lays up or down. Above "0" indicates a climb and below "0" indicates a descent, and then gauge the speed of the ascent/descent



Here the VSI shows a rate of climb of 500 feet per minute.

End of Training Tutorial



- This is the end of your training on the principles of flight
- Please feel free to review any concepts that you have not mastered
- Keep in mind that you will be tested later
- To terminate the training tutorial press the “Terminate Tutorial” button below

**TERMINATE
TUTORIAL**

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Airplane Moving Parts



This section teaches you about the three main control surfaces an airplane uses to steer. Please make sure to cover all three links below to access specific information about each concept.



Ailerons



Rudder



Elevators

The Rudder (1 of 8)



The **rudder** is attached to the back of the **vertical stabilizer**, located on the top of the airplane's tail.

The Rudder (2 of 8)

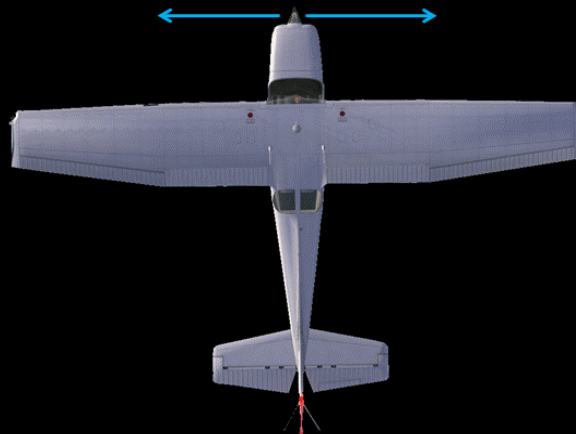


The Rudder (3 of 8)



Pilots use the **rudder** to move the nose of the airplane left and right. This is known as **yaw** movement.

The Rudder (4 of 8)

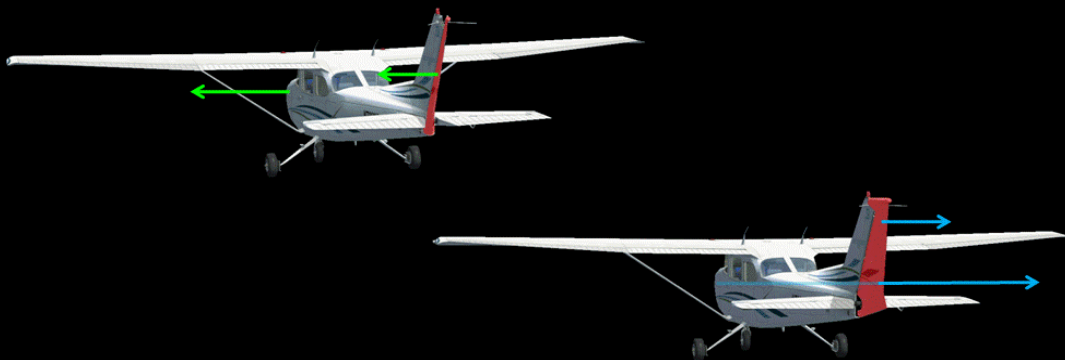


The Rudder (5 of 8)



When the rudder moves left, the nose of the airplane moves left, and when the rudder moves right, the airplane's nose moves right.

The Rudder (6 of 8)



The Rudder (7 of 8)



The rudder is used in combination with the ailerons to initiate a turn.

The Rudder (8 of 8)



The Ailerons (1 of 6)



The **aileron**s extend from about the midpoint of each wing outward to the tip.

The Ailerons (2 of 6)



The Ailerons (3 of 6)



The **ailerons** move in opposite directions – when one aileron goes **up**, the other goes **down**.

The Ailerons (4 of 6)

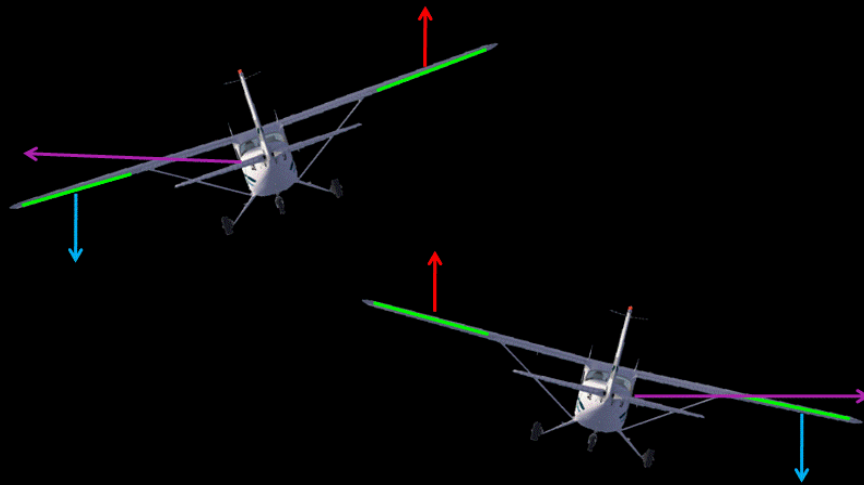


The Ailerons (5 of 6)



Pilots use the **aileron**s to **raise** one wing and **lower** the other in order to initiate a turn. This is known as either right or left **bank** movement

The Ailerons (6 of 6)

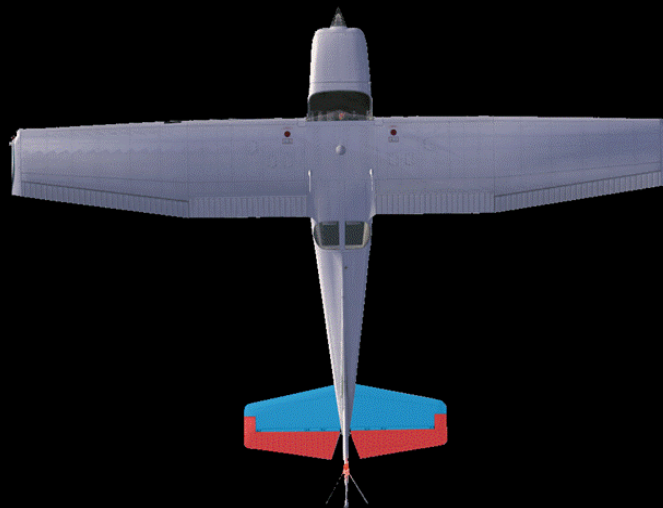


The Elevators (1 of 6)



The **elevators** are attached to the back of the **horizontal stabilizer** on the tail of the airplane.

The Elevators (2 of 6)

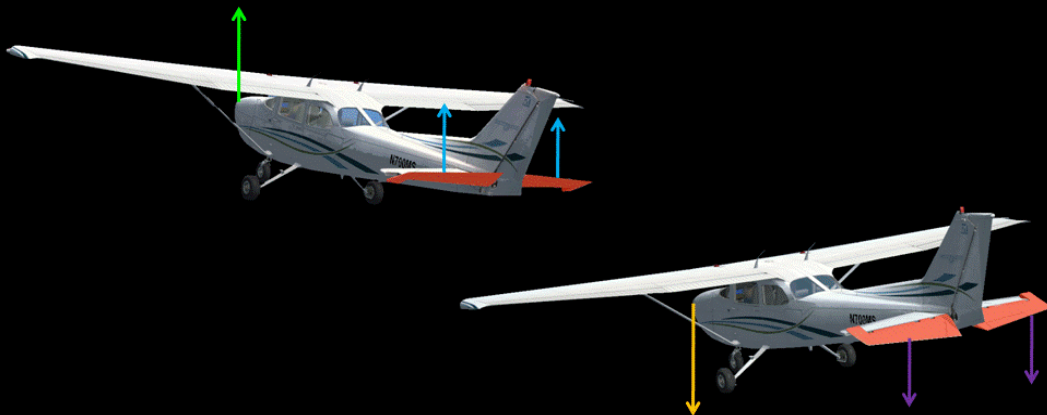


The Elevators (3 of 6)



The **elevators** move in the same direction. When they move **up**, the nose of the plane moves up to **climb**, and when they move **down**, the nose of the plane goes down to **descend**.

The Elevators (4 of 6)



The Elevators (5 of 6)



Pilots use the **elevators** to direct the airplane to the desired altitude, or height. This movement is also known as **pitch**.

The Elevators (6 of 6)



Axes of Flight



This sections teaches you about the three main axes around which an airplane moves. Please follow every link to access specific information about each moving part.

The common reference point for the three axes is the airplane's [center of gravity](#).



[Longitudinal Axis](#)



[Vertical Axis](#)



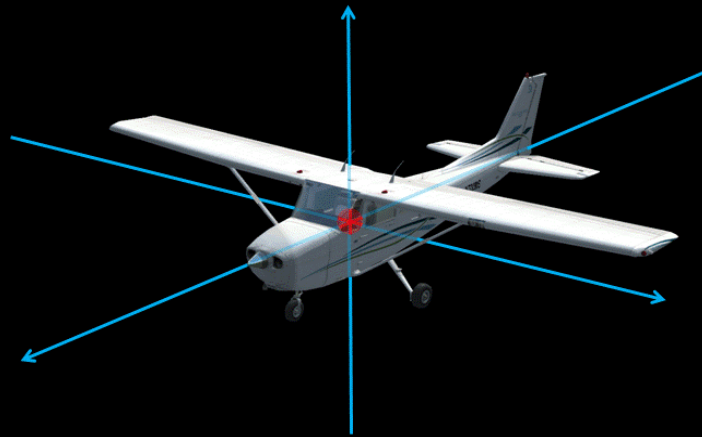
[Lateral Axis](#)

The Center of Gravity (1 of 2)



The **center of gravity** meets where the **three axes of flight** intersect. It is the theoretical point where the entire weight of the airplane is considered to be concentrated.

The Center of Gravity (2 of 2)

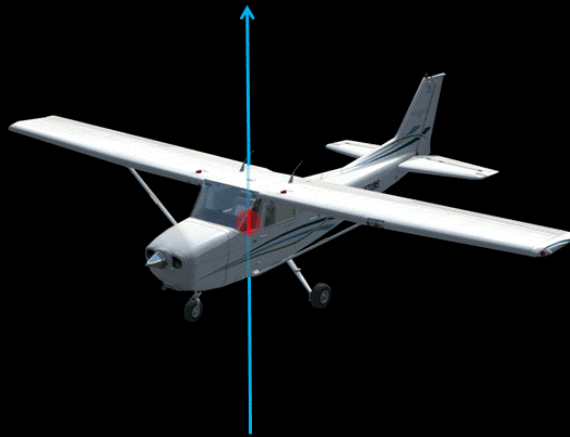


The Vertical Axis (1 of 6)



The **vertical axis** is an imaginary line that runs perpendicular to the wings through the **center of gravity**.

The Vertical Axis (2 of 6)

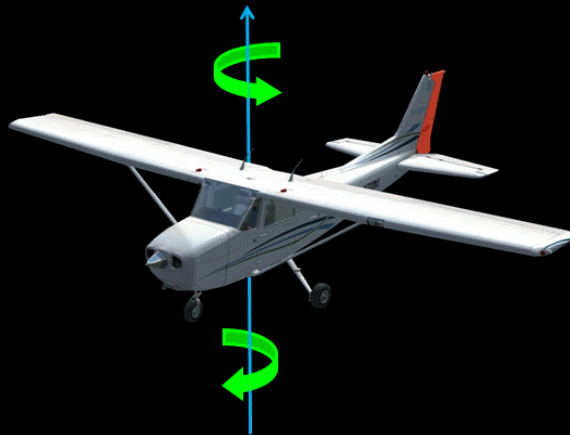


The Vertical Axis (3 of 6)



Movement around the vertical axis is performed using the rudder

The Vertical Axis (4 of 6)

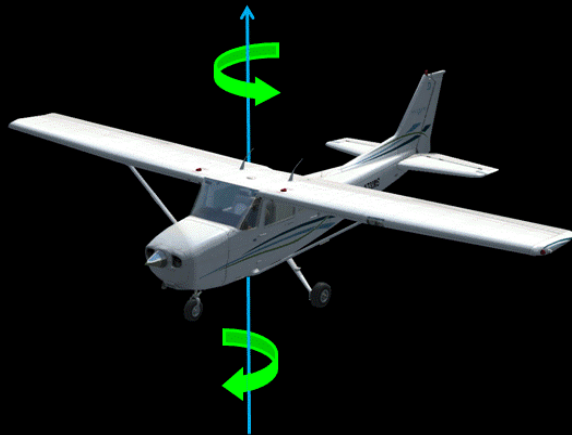


The Vertical Axis (5 of 6)



Yaw movement moves the airplane's nose left and right around the **vertical axis**

The Vertical Axis (6 of 6)



The Longitudinal Axis (1 of 6)



The **longitudinal axis** is an line that runs from the nose to the tail of the plane through the **center of gravity**.

The Longitudinal Axis (2 of 6)



The Longitudinal Axis (3 of 6)



Movement around the longitudinal axis is performed using the ailerons

The Longitudinal Axis (4 of 6)



The Longitudinal Axis (5 of 6)



Rotating around the longitudinal axis makes the plane roll, which is also called bank movement

The Longitudinal Axis (6 of 6)



The Lateral Axis (1 of 6)



The **lateral axis** that runs parallel to the wings from one wingtip to the other through the **center of gravity**.

The Lateral Axis (2 of 6)



The Lateral Axis (3 of 6)



Movement around the lateral axis is performed using the elevators

The Lateral Axis (4 of 6)



The Lateral Axis (5 of 6)



Rotating around the **lateral axis** makes the plane's nose go up and down, which is also called **pitch**

The Lateral Axis (6 of 6)



Flight Instruments



In this section, we describe the six primary flight instruments used by pilots to navigate the airplane. We will discuss how changes in the airplane's movements affect the information displayed on the instrument.

The six primary instruments are divided into the two categories below. Please, learn about all the instruments in one category before proceeding to the instruments in the other category.



Gyroscopic Instruments



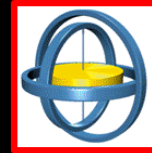
Pitot-static Instruments



Gyroscopic Instruments



A **gyroscope** is a device with, at its center, a **spinning wheel** mounted on an **axle** for measuring or maintaining orientation.



The **gyroscopic instruments** provide the pilot with a pictorial view of the airplane's attitude (top middle), rate of turn (bottom left), and heading (bottom middle).



Please, access the links below to learn about each instrument



[Attitude Indicator](#)



[Turn Coordinator](#)



[Heading Indicator](#)

The Attitude Indicator (AI) – 1 of 12



The **attitude indicator (AI)** is used as an artificial horizon when the **true horizon** is not visible. The **AI** alone can't tell you whether the airplane is maintaining level flight, climbing, or descending. It simply shows the **aircraft's attitude** relative to the **horizon**.

The Attitude Indicator (AI) – 2 of 12



The Attitude Indicator (AI) – 3 of 12



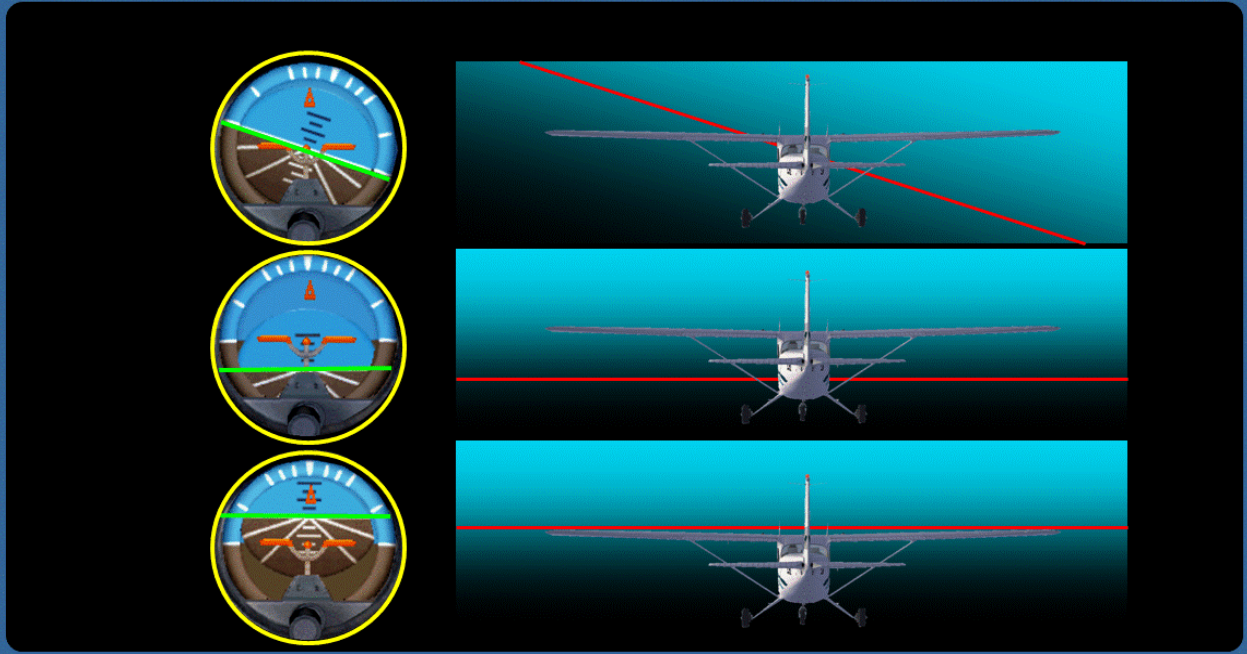
The AI maintains its orientation relative to the true horizon as the airplane:

banks

climbs

descends

The Attitude Indicator (AI) – 4 of 12



The Attitude Indicator (AI) – 5 of 12



The artificial miniature airplane at the center of the AI is used as a point of reference. The AI typically has a blue "sky" and brown "earth."

The Attitude Indicator (AI) – 6 of 12



The Attitude Indicator (AI) – 7 of 12



When the plane **climbs**, the **AI** shows more **blue**

When the plane **descends**, the **AI** shows more **brown**

The Attitude Indicator (AI) – 8 of 12



The Attitude Indicator (AI) – 9 of 12



When the plane banks towards the left (moving on the longitudinal axis), the AI rotates clockwise.

The Attitude Indicator (AI) – 10 of 12

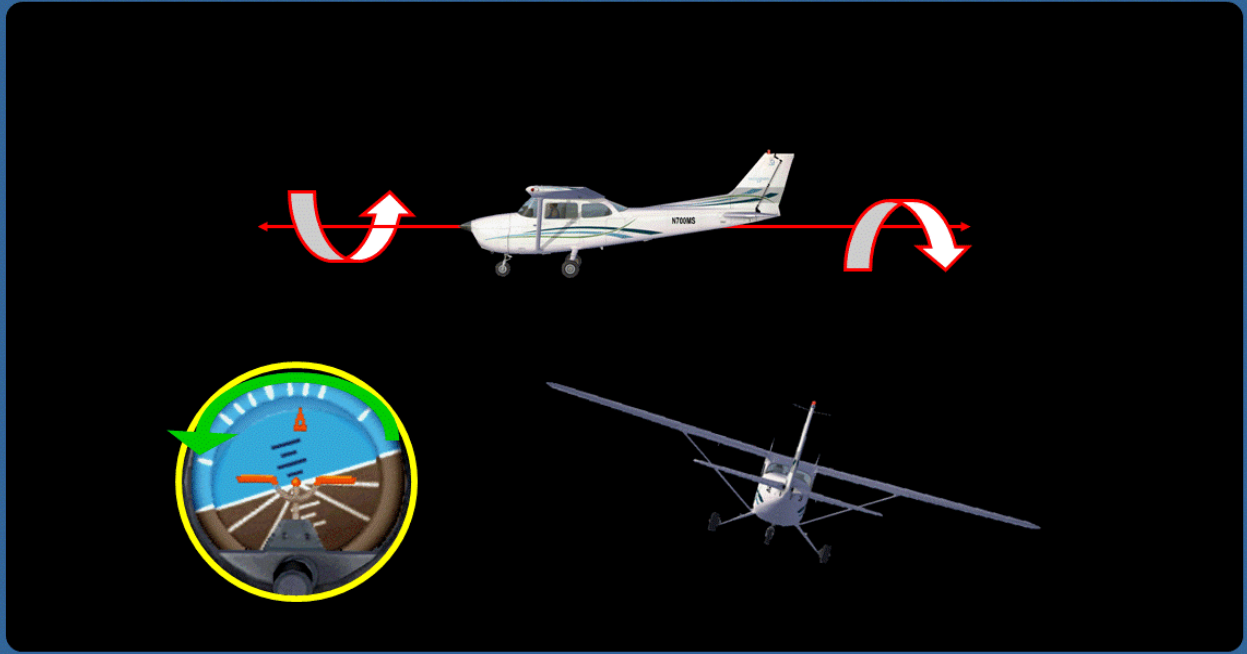


The Attitude Indicator (AI) – 11 of 12



When the plane banks towards the right (moving on the longitudinal axis), the AI rotates counter-clockwise.

The Attitude Indicator (AI) – 12 of 12

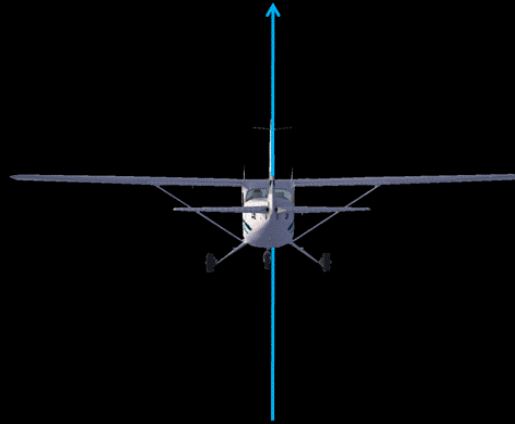


The Turn Coordinator (TC) – 1 of 10



The **turn coordinator** is used to show the aircraft's rate of turn—how fast it's changing direction. A mechanism in the turn coordinator is oriented such that when the airplane turns on the **vertical axis** it forces the **miniature airplane** on the TC to **turn**.

The Turn Coordinator (TC) – 2 of 10



The Turn Coordinator (TC) – 3 of 10



The rate of movement makes the TC's miniature airplane lean to the left or right.

The Turn Coordinator (TC) – 4 of 10



The Turn Coordinator (TC) – 5 of 10



When the wings of the **miniature airplane** align with the lines next to the "L" and "R," the aircraft is making a **standard rate turn**:

Standard rate turn
to the **left**

Standard rate turn
to the **right**

The Turn Coordinator (TC) – 6 of 10

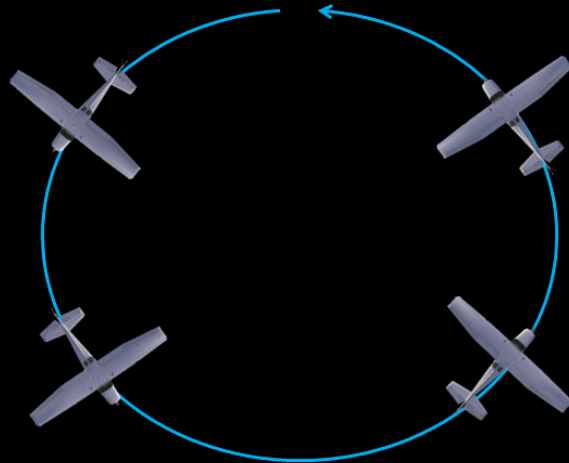


The Turn Coordinator (TC) – 7 of 10



A **standard rate turn** indicates that the aircraft completes a **360-degree turn** in **two minutes**.

The Turn Coordinator (TC) – 8 of 10



The Turn Coordinator (TC) – 9 of 10



The faster the turn, the greater the movement, and the steeper the lean of the TC's miniature airplane:

Standard rate turn
to the left

Steep turn to
the right

The Turn Coordinator (TC) – 10 of 10



The Heading Indicator (HI) – 1 of 8



The heading indicator is sometimes called the “compass card.” The HI provides a smooth and precise indication of heading or turns as a result of yaw movement.

The Heading Indicator (HI) – 2 of 8



The Heading Indicator (HI) – 3 of 8



A card in the HI that is marked with heading degrees maintains its orientation as the actual airplane turns. Thus, the miniature airplane at the center of the HI always remains pointing upward, only this heading card rotates.

The Heading Indicator (HI) – 4 of 8



The Heading Indicator (HI) – 5 of 8



The card in the HI is marked off with numbers every 30 degrees and the cardinal directions indicated by N (North), S (South), E (East), W (West).

The Heading Indicator (HI) – 6 of 8



The Heading Indicator (HI) – 7 of 8



To read the numbers on the HI, simply “add” a zero. For example:

The HI is pointing to the “6,” which indicates a “60 degrees” heading

The HI is pointing to the “21,” which indicates a “210 degrees” heading

The Heading Indicator (HI) – 8 of 8



Pitot-Static Instruments



A Pitot-static system consists of a system of pressure-sensitive instruments and the means by which the appropriate pressures are obtained

The **Pitot-static instruments** provide the pilot with information regarding speed (top left), altitude (top right), and rate of climb or descent (bottom right).

Please, access the links below to learn about each instrument



[Airspeed Indicator](#)



[Altimeter](#)



[Vertical Speed Indicator](#)

The Airspeed Indicator (ASI) – 1 of 4



This **airspeed indicator** is calibrated in **knots**. The **ASI** is divided into color-coded arcs that define speed ranges for different phases of flight: for **use of flaps (white)**, for **normal operations (green)**, for smooth air operations or **caution speed (yellow)**, and for maximum or “**never-exceed**” speed (red).

The Airspeed Indicator (ASI) – 2 of 4



The Airspeed Indicator (ASI) – 3 of 4



The ASI displays changes in the forward movement of the airplane:

The ASI indicates a speed of 80 knots

The ASI indicates a speed of 120 knots

The Airspeed Indicator (ASI) – 4 of 4



The Altimeter – 1 of 6



The **altimeter** displays changes in the **vertical movement** (up and down) of the airplane.

The Altimeter – 2 of 6



The Altimeter – 3 of 6



The **altimeter** usually has two pointers to indicate the airplanes' altitude. These pointers are generally arranged as follows:

A pointer with a **flared triangular tip** showing 1,000 foot intervals

A pointer with a **needle tip** showing 100 foot intervals

The Altimeter – 4 of 6



The Altimeter – 5 of 6



The **altimeter** is numbered 0 through 9. How to read the altitude on the example below:

First read the **flared triangular tip**. Here it rests between **2 and 3** (indicating an altitude above 2,000 feet)

Second, read the **needle tip**. Here it rests between **7 and 8** (indicating an at least 700 feet). Actually, it is $\frac{3}{5}$ th of the way to 8, indicating 760 feet.

Finally, add the two values. Here we have $2,000 + 760$ indicating an altitude of 2,760

The Altimeter – 6 of 6

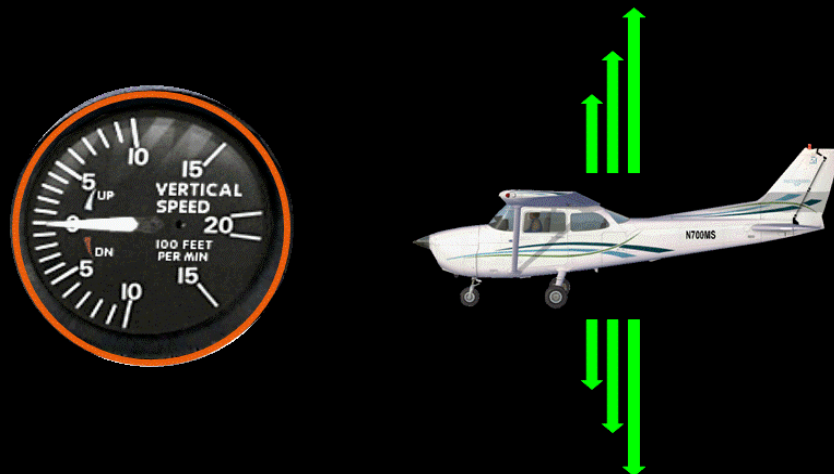


The Vertical Speed Indicator (VSI) – 1 of 4



The vertical speed indicator displays changes in the vertical rate of movement of the airplane when it climbs or descends, that is, how fast it goes up or down.

The Vertical Speed Indicator (VSI) – 2 of 4



The Vertical Speed Indicator (VSI) – 3 of 4



The VSI is calibrated in 100 feet per minute intervals. To read the VSI, first determine if the needle lays up or down. Above “0” indicates a climb and below “0” indicates a descent, and then gauge the speed of the ascent/descent

Here the VSI shows a rate of climb of 500 feet per minute.

The Vertical Speed Indicator (VSI) – 4 of 4



End of Training Tutorial



- This is the end of your training on the principles of flight
- Please feel free to review any concepts that you have not mastered
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- To terminate the training tutorial press the “Terminate Tutorial” button below

**TERMINATE
TUTORIAL**

Principles of Flight Training Tutorial



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- You are free to learn these concepts at your own pace, as there is no time limit
- Please review the information below explaining how to navigate this tutorial
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Concept

Click underlined concepts to access learning content



Click on the arrow buttons on the top-right portion of the screen to go back and forth in this tutorial



Click the "return to menu" button located next to the arrows to go back to the concepts menu



A checkmark will appear next to the links that you have accessed

Airplane Moving Parts



This section teaches you about the three main control surfaces an airplane uses to steer. Please make sure to cover all three links below to access specific information about each concept.



Ailerons



Rudder



Elevators

The Rudder (1 of 8)



The **rudder** is attached to the back of the **vertical stabilizer**, located on the top of the airplane's tail.

The Rudder (2 of 8)

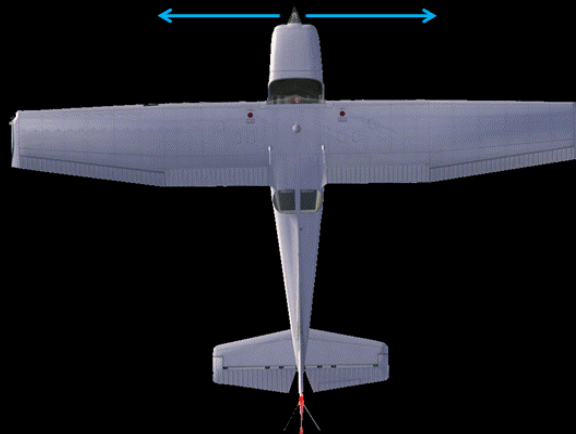


The Rudder (3 of 8)



Pilots use the **rudder** to move the nose of the airplane left and right. This is known as **yaw** movement.

The Rudder (4 of 8)

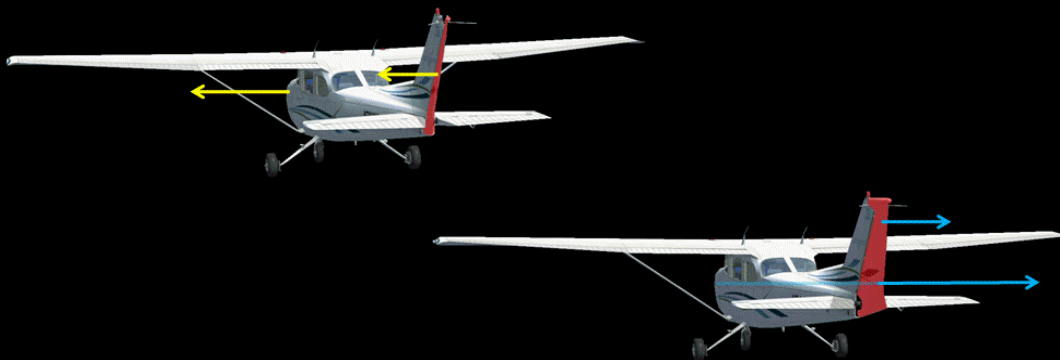


The Rudder (5 of 8)



When the **rudder** moves **left**, the nose of the airplane moves **left**, and when the **rudder** moves **right**, the airplane's nose moves **right**.

The Rudder (6 of 8)



The Rudder (7 of 8)



The **rudder** is used in combination with the **ailerons** to initiate a **turn**.

The Rudder (8 of 8)



The Ailerons (1 of 6)



The **aileron**s extend from about the midpoint of each wing outward to the tip.

The Ailerons (2 of 6)



The Ailerons (3 of 6)



The **aileron**s move in opposite directions – when one aileron goes **up**, the other goes **down**.

The Ailerons (4 of 6)

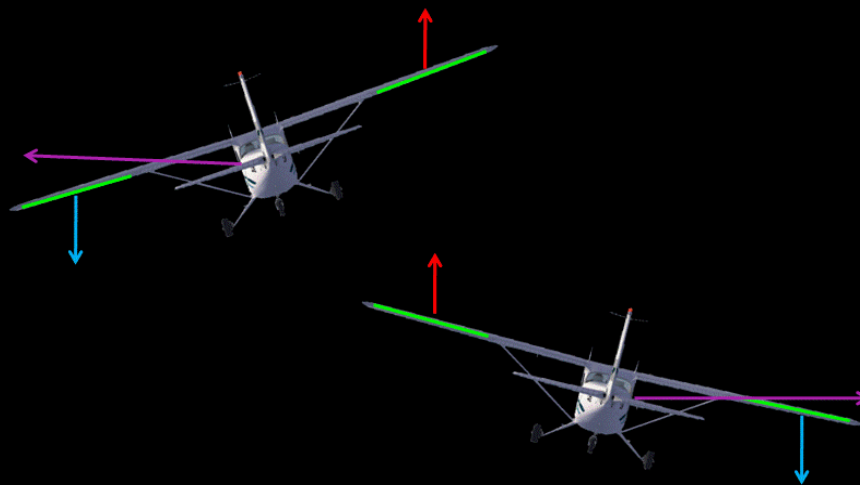


The Ailerons (5 of 6)



Pilots use the **aileron**s to **raise** one wing and **lower** the other in order to initiate a turn. This is known as either right or left **bank** movement

The Ailerons (6 of 6)



The Elevators (1 of 6)



The **elevators** are attached to the back of the **horizontal stabilizer** on the tail of the airplane.

The Elevators (2 of 6)

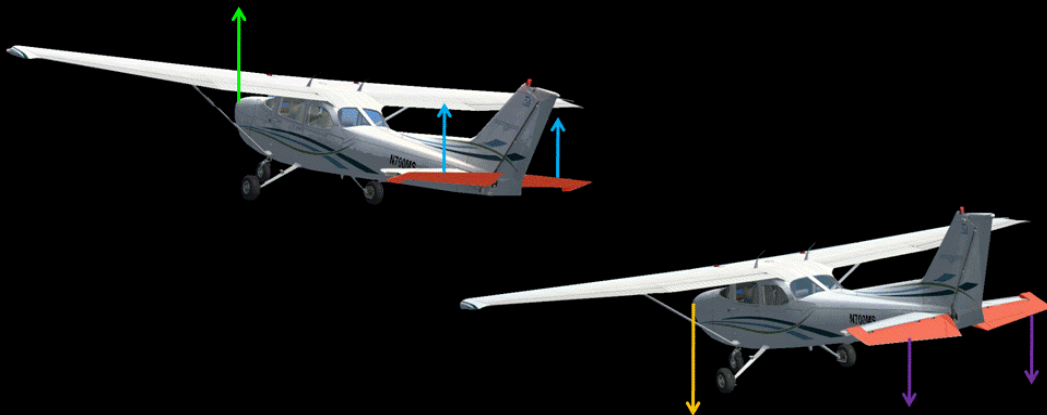


The Elevators (3 of 6)



The **elevators** move in the same direction. When they move **up**, the nose of the plane moves up to **climb**, and when they move **down**, the nose of the plane goes down to **descend**.

The Elevators (4 of 6)



The Elevators (5 of 6)



Pilots use the **elevators** to direct the airplane to the desired altitude, or height. This movement is also known as **pitch**.

The Elevators (6 of 6)



Axes of Flight



This sections teaches you about the three main axes around which an airplane moves. Please follow every link to access specific information about each moving part.

The common reference point for the three axes is the airplane's [center of gravity](#).



[Longitudinal Axis](#)



[Vertical Axis](#)



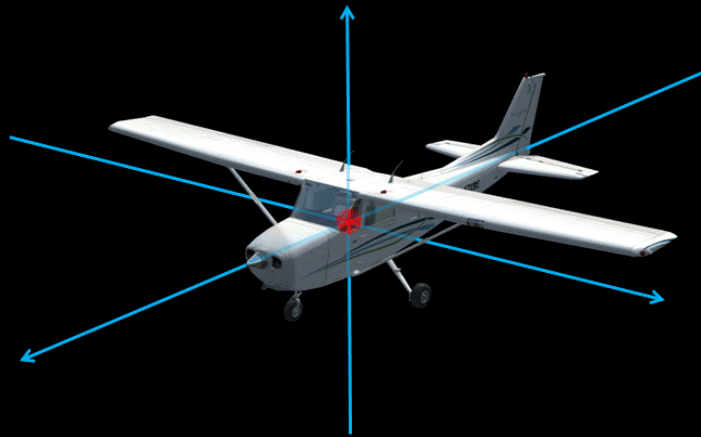
[Lateral Axis](#)

The Center of Gravity (1 of 2)



The [center of gravity](#) meets where the [three axes of flight](#) intersect. It is the theoretical point where the entire weight of the airplane is considered to be concentrated.

The Center of Gravity (2 of 2)

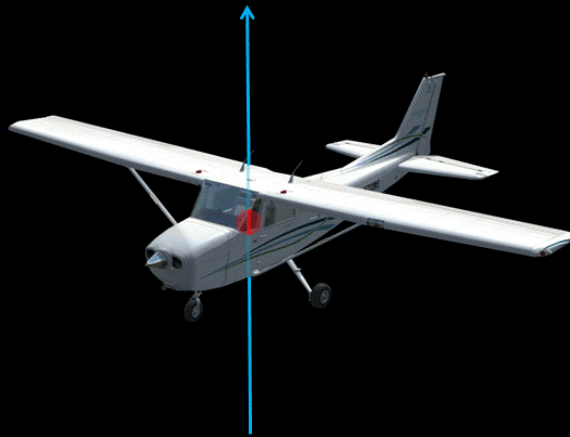


The Vertical Axis (1 of 6)



The **vertical axis** is an imaginary line that runs perpendicular to the wings through the **center of gravity**.

The Vertical Axis (2 of 6)

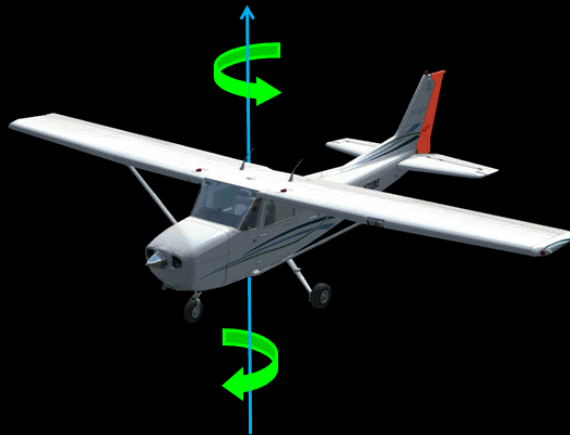


The Vertical Axis (3 of 6)



Movement around the **vertical axis** is performed using the **rudder**

The Vertical Axis (4 of 6)

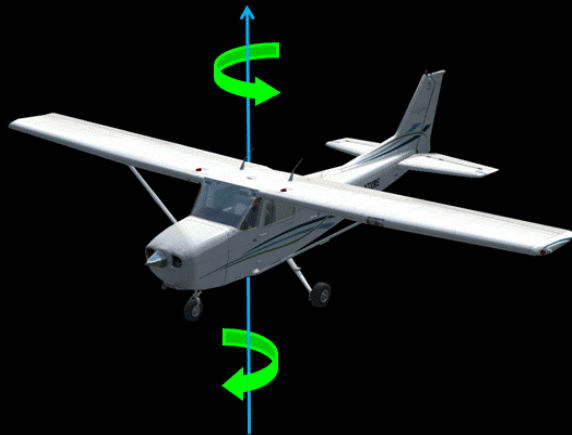


The Vertical Axis (5 of 6)



Yaw movement moves the airplane's nose left and right around the vertical axis

The Vertical Axis (6 of 6)



The Longitudinal Axis (1 of 6)



The **longitudinal axis** is an line that runs from the nose to the tail of the plane through the **center of gravity**.

The Longitudinal Axis (2 of 6)



The Longitudinal Axis (3 of 6)



Movement around the **longitudinal axis** is performed using the **ailerons**

The Longitudinal Axis (4 of 6)



The Longitudinal Axis (5 of 6)



Rotating around the longitudinal axis makes the plane roll, which is also called bank movement

The Longitudinal Axis (6 of 6)



The Lateral Axis (1 of 6)



The **lateral axis** that runs parallel to the wings from one wingtip to the other through the **center of gravity**.

The Lateral Axis (2 of 6)



The Lateral Axis (3 of 6)



Movement around the **lateral axis** is performed using the **elevators**

The Lateral Axis (4 of 6)



The Lateral Axis (5 of 6)



Rotating around the **lateral axis** makes the plane's nose go up and down, which is also called **pitch**

The Lateral Axis (6 of 6)



Flight Instruments



In this section, we describe the six primary flight instruments used by pilots to navigate the airplane. We will discuss how changes in the airplane's movements affect the information displayed on the instrument.

The six primary instruments are divided into the two categories below. Please, learn about all the instruments in one category before proceeding to the instruments in the other category.



Gyroscopic Instruments



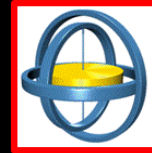
Pitot-static Instruments



Gyroscopic Instruments



A **gyroscope** is a device with, at its center, a **spinning wheel** mounted on an **axle** for measuring or maintaining orientation.



The **gyroscopic instruments** provide the pilot with a pictorial view of the airplane's attitude (top middle), rate of turn (bottom left), and heading (bottom middle).



Please, access the links below to learn about each instrument



[Attitude Indicator](#)



[Turn Coordinator](#)



[Heading Indicator](#)

The Attitude Indicator (AI) – 1 of 12



The **attitude indicator (AI)** is used as an artificial horizon when the **true horizon** is not visible. The **AI** alone can't tell you whether the airplane is maintaining level flight, climbing, or descending. It simply shows the **aircraft's attitude** relative to the **horizon**.

The Attitude Indicator (AI) – 2 of 12



The Attitude Indicator (AI) – 3 of 12



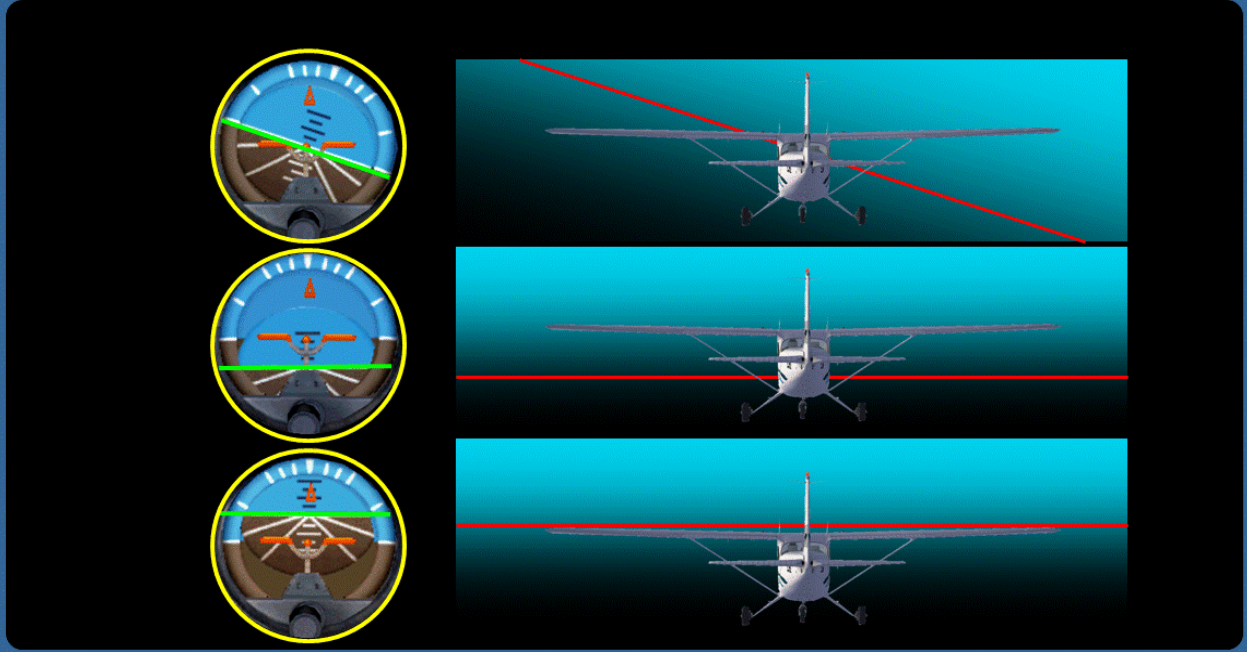
The AI maintains its orientation relative to the true horizon as the airplane:

banks

climbs

descends

The Attitude Indicator (AI) – 4 of 12



The Attitude Indicator (AI) – 5 of 12



The artificial miniature airplane at the center of the AI is used as a point of reference. The AI typically has a blue "sky" and brown "earth."

The Attitude Indicator (AI) – 6 of 12



The Attitude Indicator (AI) – 7 of 12



When the plane **climbs**, the **AI** shows more **blue**

When the plane **descends**, the **AI** shows more **brown**

The Attitude Indicator (AI) – 8 of 12



The Attitude Indicator (AI) – 9 of 12



When the plane banks towards the left (moving on the longitudinal axis), the AI rotates clockwise.

The Attitude Indicator (AI) – 10 of 12

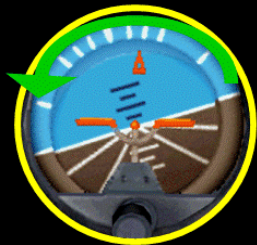


The Attitude Indicator (AI) – 11 of 12



When the plane banks towards the right (moving on the longitudinal axis), the AI rotates counter-clockwise.

The Attitude Indicator (AI) – 12 of 12

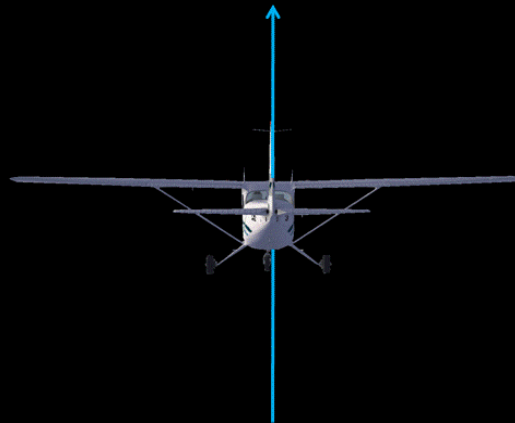


The Turn Coordinator (TC) – 1 of 10



The **turn coordinator** is used to show the aircraft's rate of turn—how fast it's changing direction. A mechanism in the turn coordinator is oriented such that when the airplane turns on the **vertical axis** it forces the **miniature airplane** on the TC to **turn**.

The Turn Coordinator (TC) – 2 of 10



The Turn Coordinator (TC) – 3 of 10



The rate of movement makes the TC's miniature airplane lean to the left or right.

The Turn Coordinator (TC) – 4 of 10



The Turn Coordinator (TC) – 5 of 10



When the wings of the miniature airplane align with the lines next to the "L" and "R," the aircraft is making a standard rate turn:

Standard rate turn
to the left

Standard rate turn
to the right

The Turn Coordinator (TC) – 6 of 10

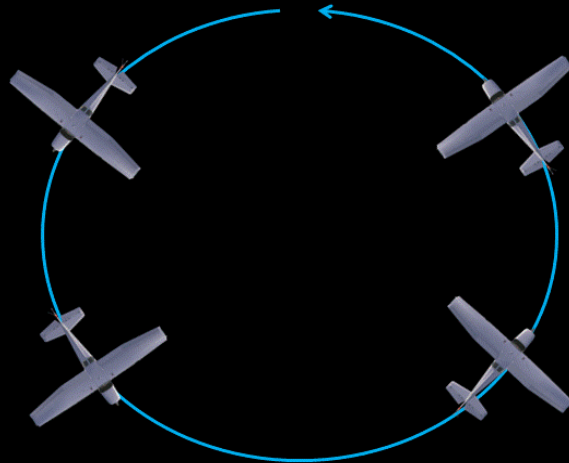


The Turn Coordinator (TC) – 7 of 10



A **standard rate turn** indicates that the aircraft completes a **360-degree turn** in **two minutes**.

The Turn Coordinator (TC) – 8 of 10



The Turn Coordinator (TC) – 9 of 10



The faster the turn, the greater the movement, and the steeper the lean of the TC's miniature airplane:

Standard rate turn
to the left

Steep turn to
the right

The Turn Coordinator (TC) – 10 of 10



The Heading Indicator (HI) – 1 of 8



The heading indicator is sometimes called the “compass card.” The HI provides a smooth and precise indication of heading or turns as a result of yaw movement.

The Heading Indicator (HI) – 2 of 8



The Heading Indicator (HI) – 3 of 8



A card in the HI that is marked with heading degrees maintains its orientation as the actual airplane turns. Thus, the miniature airplane at the center of the HI always remains pointing upward, only this heading card rotates.

The Heading Indicator (HI) – 4 of 8



The Heading Indicator (HI) – 5 of 8



The card in the HI is marked off with numbers every 30 degrees and the cardinal directions indicated by N (North), S (South), E (East), W (West).

The Heading Indicator (HI) – 6 of 8



The Heading Indicator (HI) – 7 of 8



To read the numbers on the HI, simply “add” a zero. For example:

The HI is pointing to the “6,” which indicates a “60 degrees” heading

The HI is pointing to the “21,” which indicates a “210 degrees” heading

The Heading Indicator (HI) – 8 of 8



Pitot-Static Instruments



A Pitot-static system consists of a system of pressure-sensitive instruments and the means by which the appropriate pressures are obtained

The [Pitot-static instruments](#) provide the pilot with information regarding speed (top left), altitude (top right), and rate of climb or descent (bottom right).

Please, access the links below to learn about each instrument



[Airspeed Indicator](#)



[Altimeter](#)



[Vertical Speed Indicator](#)

The Airspeed Indicator (ASI) – 1 of 4



This **airspeed indicator** is calibrated in **knots**. The **ASI** is divided into color-coded arcs that define speed ranges for different phases of flight: for **use of flaps (white)**, for **normal operations (green)**, for smooth air operations or **caution speed (yellow)**, and for maximum or “**never-exceed**” speed (red).

The Airspeed Indicator (ASI) – 2 of 4



The Airspeed Indicator (ASI) – 3 of 4



The ASI displays changes in the forward movement of the airplane:

The ASI indicates a speed of 80 knots

The ASI indicates a speed of 120 knots

The Airspeed Indicator (ASI) – 4 of 4

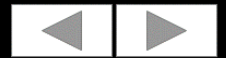


The Altimeter – 1 of 6



The **altimeter** displays changes in the **vertical movement** (up and down) of the airplane.

The Altimeter – 2 of 6



The Altimeter – 3 of 6



The **altimeter** usually has two pointers to indicate the airplanes' altitude. These pointers are generally arranged as follows:

A pointer with a **flared triangular tip** showing 1,000 foot intervals

A pointer with a **needle tip** showing 100 foot intervals

The Altimeter – 4 of 6



The Altimeter – 5 of 6



The **altimeter** is numbered 0 through 9. How to read the altitude on the example below:

First read the **flared triangular tip**. Here it rests between **2 and 3** (indicating an altitude above 2,000 feet)

Second, read the **needle tip**. Here it rests between **7 and 8** (indicating an at least 700 feet). Actually, it is $\frac{3}{5}$ th of the way to 8, indicating 760 feet.

Finally, add the two values. Here we have $2,000 + 760$ indicating an altitude of 2,760

The Altimeter – 6 of 6

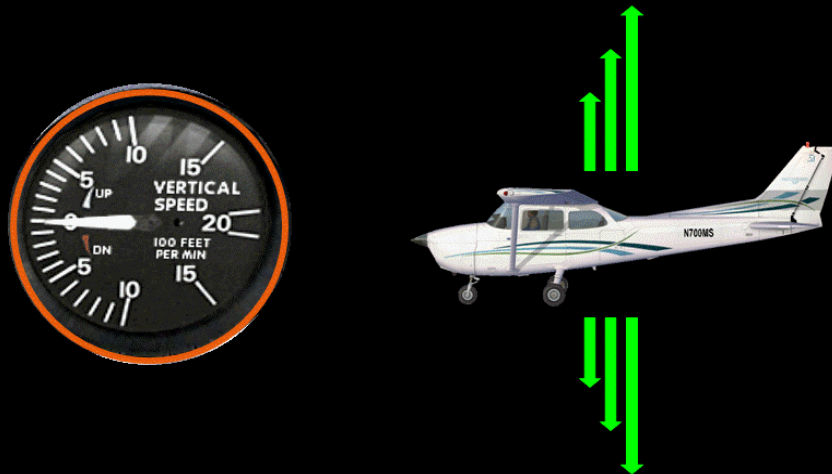


The Vertical Speed Indicator (VSI) – 1 of 4



The vertical speed indicator displays changes in the vertical rate of movement of the airplane when it climbs or descends, that is, how fast it goes up or down.

The Vertical Speed Indicator (VSI) – 2 of 4



The Vertical Speed Indicator (VSI) – 3 of 4



The VSI is calibrated in 100 feet per minute intervals. To read the VSI, first determine if the needle lays up or down. Above “0” indicates a climb and below “0” indicates a descent, and then gauge the speed of the ascent/descent

Here the VSI shows a rate of climb of 500 feet per minute.

The Vertical Speed Indicator (VSI) – 4 of 4



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Airplane Moving Parts



This section teaches you about the three main control surfaces an airplane uses to steer. Please make sure to cover all three links below to access specific information about each concept.



Ailerons



Rudder



Elevators

The Rudder (1 of 8)



The rudder is attached to the back of the vertical stabilizer, located on the top of the airplane's tail.

The Rudder (2 of 8)

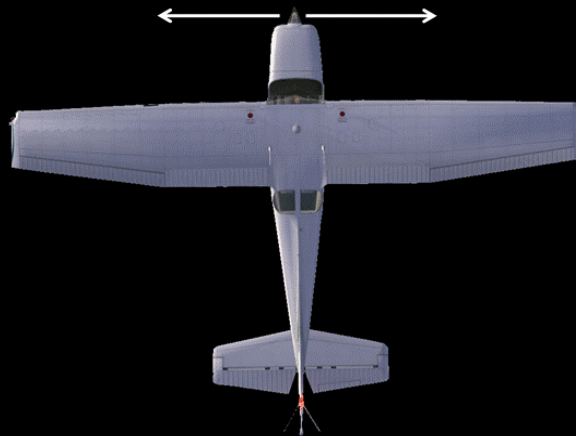


The Rudder (3 of 8)



Pilots use the rudder to move the nose of the airplane left and right. This is known as yaw movement.

The Rudder (4 of 8)

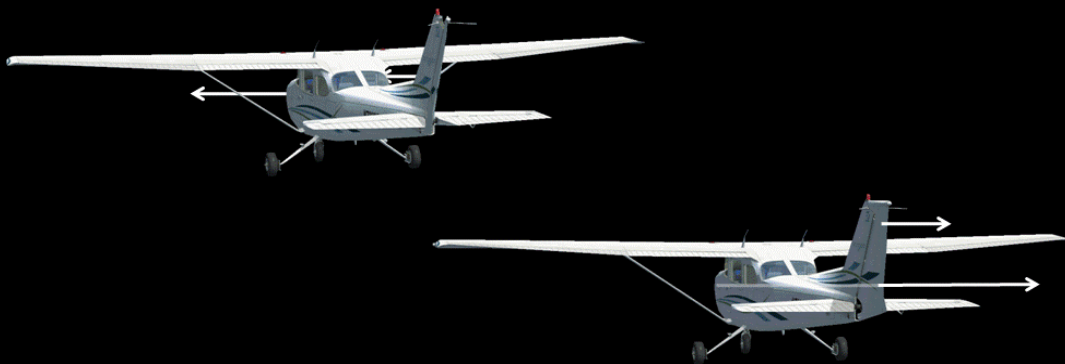


The Rudder (5 of 8)



When the rudder moves left, the nose of the airplane moves left, and when the rudder moves right, the airplane's nose moves right.

The Rudder (6 of 8)



The Rudder (7 of 8)



The rudder is used in combination with the ailerons to initiate a turn.

The Rudder (8 of 8)



The Ailerons (1 of 6)



The ailerons extend from about the midpoint of each wing outward to the tip.

The Ailerons (2 of 6)



The Ailerons (3 of 6)



The ailerons move in opposite directions – when one aileron goes up, the other goes down.

The Ailerons (4 of 6)

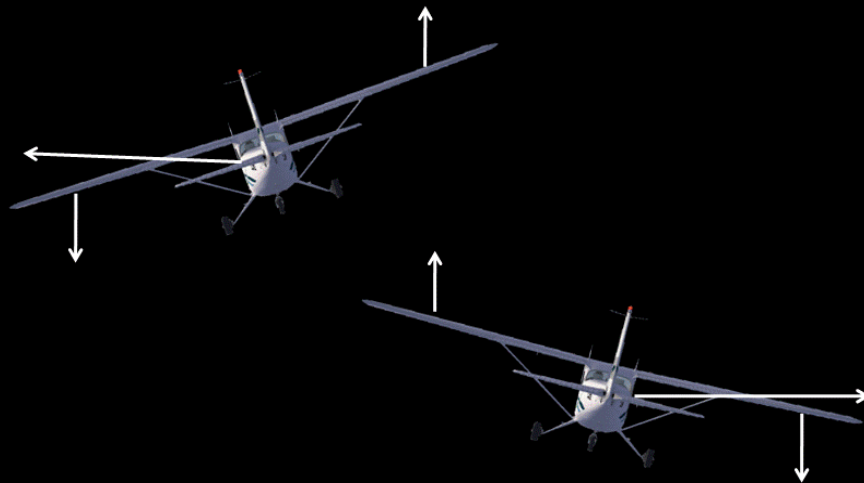


The Ailerons (5 of 6)



Pilots use the ailerons to raise one wing and lower the other in order to initiate a turn. This is known as either right or left bank movement

The Ailerons (6 of 6)



The Elevators (1 of 6)



The elevators are attached to the back of the horizontal stabilizer on the tail of the airplane.

The Elevators (2 of 6)

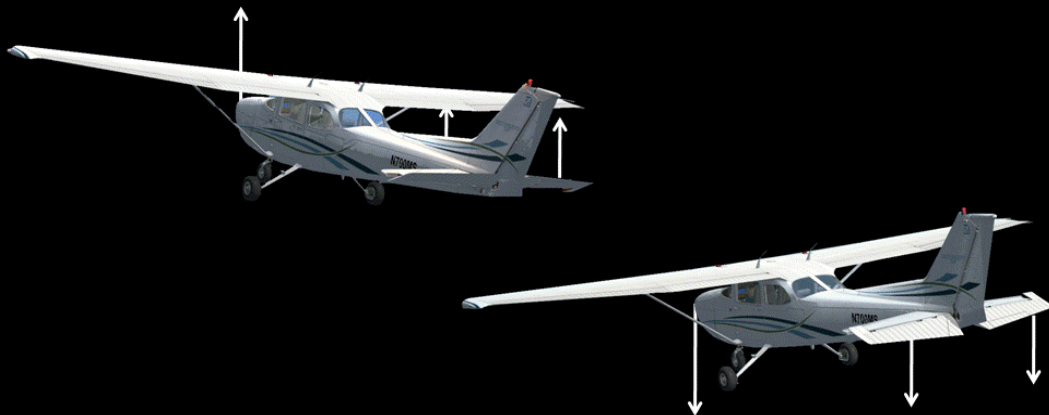


The Elevators (3 of 6)



The elevators move in the same direction. When they move up, the nose of the plane moves up to climb, and when they move down, the nose of the plane goes down to descend.

The Elevators (4 of 6)



The Elevators (5 of 6)



Pilots use the elevators to direct the airplane to the desired altitude, or height. This movement is also known as pitch.

The Elevators (6 of 6)



Axes of Flight



This sections teaches you about the three main axes around which an airplane moves. Please follow every link to access specific information about each moving part.

The common reference point for the three axes is the airplane's [center of gravity](#).



[Longitudinal Axis](#)



[Vertical Axis](#)



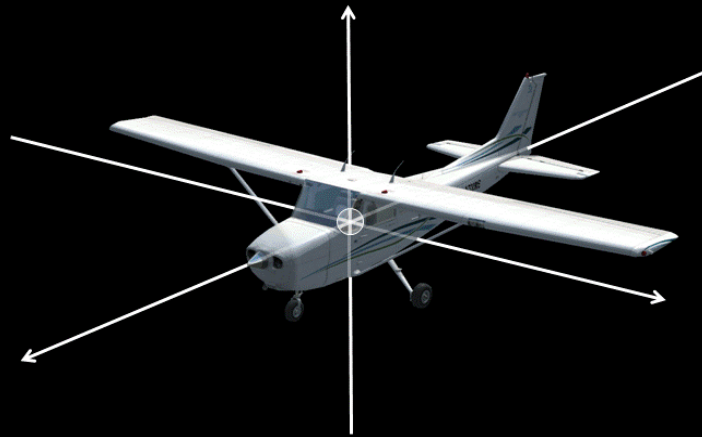
[Lateral Axis](#)

The Center of Gravity (1 of 2)



The center of gravity meets where the three axes of flight intersect. It is the theoretical point where the entire weight of the airplane is considered to be concentrated.

The Center of Gravity (2 of 2)

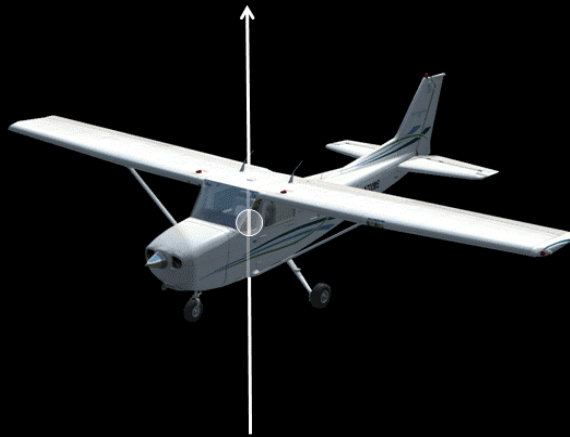


The Vertical Axis (1 of 6)



The vertical axis is an imaginary line that runs perpendicular to the wings through the center of gravity.

The Vertical Axis (2 of 6)

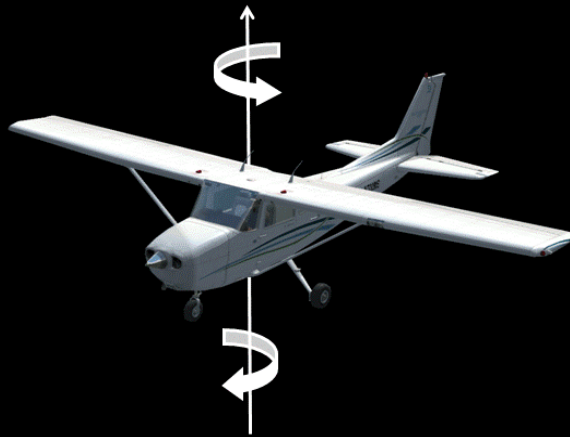


The Vertical Axis (3 of 6)



Movement around the vertical axis is performed using the rudder

The Vertical Axis (4 of 6)

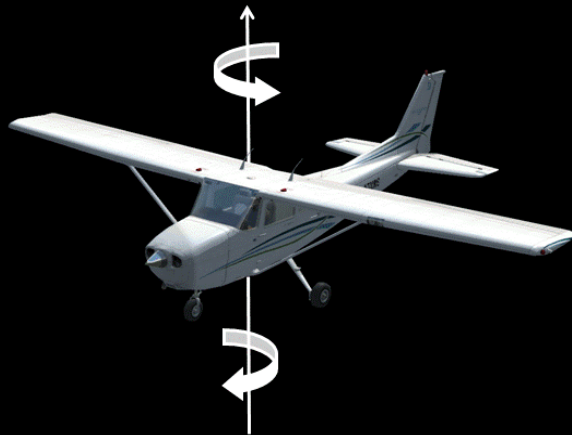


The Vertical Axis (5 of 6)



Yaw movement moves the airplane's nose
left and right around the vertical axis

The Vertical Axis (6 of 6)



The Longitudinal Axis (1 of 6)



The longitudinal axis is an line that runs from the nose to the tail of the plane through the center of gravity.

The Longitudinal Axis (2 of 6)



The Longitudinal Axis (3 of 6)



Movement around the longitudinal axis is performed using the ailerons

The Longitudinal Axis (4 of 6)



The Longitudinal Axis (5 of 6)



Rotating around the longitudinal axis makes the plane roll, which is also called bank movement

The Longitudinal Axis (6 of 6)



The Lateral Axis (1 of 6)



The lateral axis that runs parallel to the wings from one wingtip to the other through the center of gravity.

The Lateral Axis (2 of 6)



The Lateral Axis (3 of 6)



Movement around the lateral axis is performed using the elevators

The Lateral Axis (4 of 6)



The Lateral Axis (5 of 6)

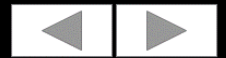


Rotating around the lateral axis makes the plane's nose go up and down, which is also called pitch

The Lateral Axis (6 of 6)



Flight Instruments



In this section, we describe the six primary flight instruments used by pilots to navigate the airplane. We will discuss how changes in the airplane's movements affect the information displayed on the instrument.

The six primary instruments are divided into the two categories below. Please, learn about all the instruments in one category before proceeding to the instruments in the other category.



Gyroscopic Instruments



Pitot-static Instruments



Gyroscopic Instruments



A **gyroscope** is a device with, at its center, a spinning wheel mounted on an axle for measuring or maintaining orientation.



The gyroscopic instruments provide the pilot with a pictorial view of the airplane's attitude (top middle), rate of turn (bottom left), and heading (bottom middle).



Please, access the links below to learn about each instrument



[Attitude Indicator](#)



[Turn Coordinator](#)



[Heading Indicator](#)

The Attitude Indicator (AI) – 1 of 12



The attitude indicator (AI) is used as an artificial horizon when the true horizon is not visible. The AI alone can't tell you whether the airplane is maintaining level flight, climbing, or descending. It simply shows the aircraft's attitude relative to the horizon.

The Attitude Indicator (AI) – 2 of 12



The Attitude Indicator (AI) – 3 of 12



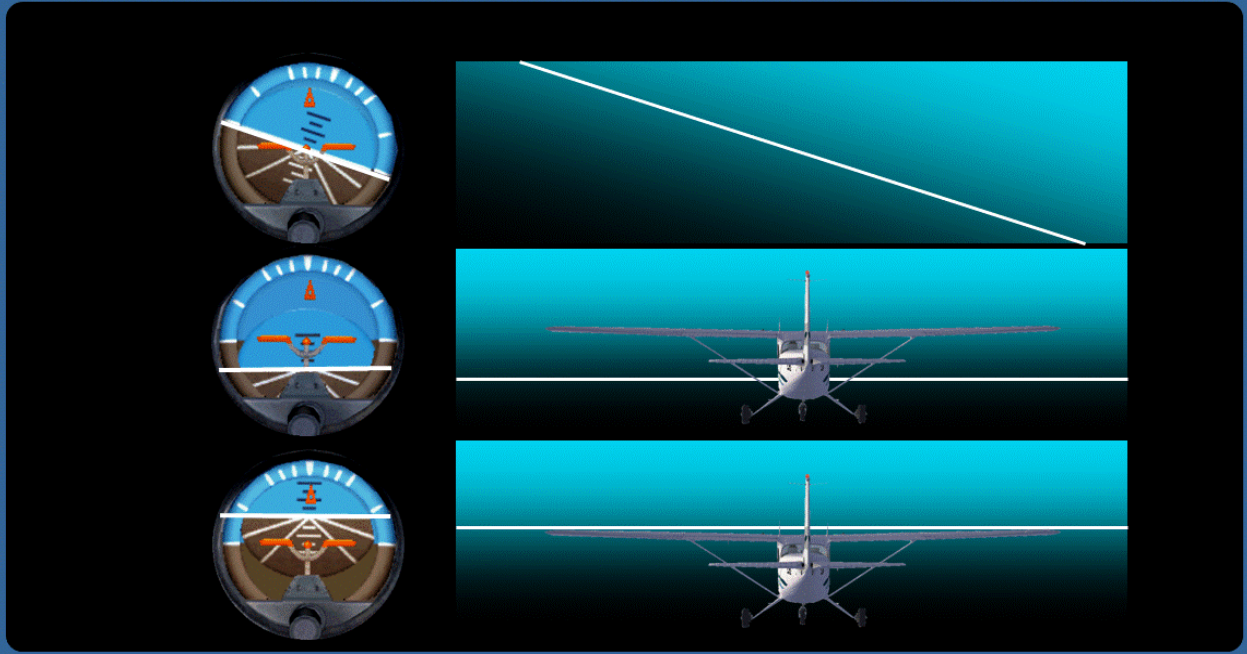
The AI maintains its orientation relative to the true horizon as the airplane:

banks

climbs

descends

The Attitude Indicator (AI) – 4 of 12



The Attitude Indicator (AI) – 5 of 12



The artificial miniature airplane at the center of the AI is used as a point of reference. The AI typically has a blue "sky" and brown "earth."

The Attitude Indicator (AI) – 6 of 12



The Attitude Indicator (AI) – 7 of 12



When the plane climbs, the AI shows more blue

When the plane descends, the AI shows more brown

The Attitude Indicator (AI) – 8 of 12



The Attitude Indicator (AI) – 9 of 12



When the plane banks towards the left (moving on the longitudinal axis), the AI rotates clockwise.

The Attitude Indicator (AI) – 10 of 12



The Attitude Indicator (AI) – 11 of 12



When the plane banks towards the right (moving on the longitudinal axis), the AI rotates counter-clockwise.

The Attitude Indicator (AI) – 12 of 12

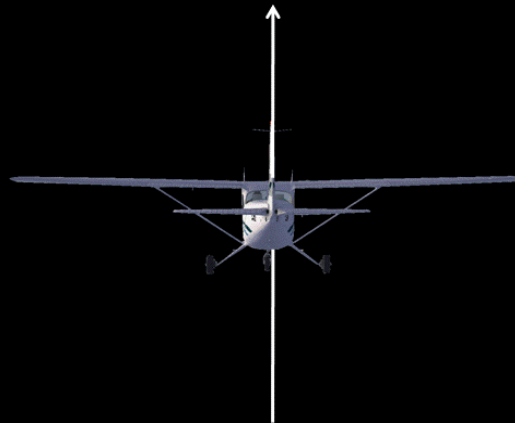


The Turn Coordinator (TC) – 1 of 10



The turn coordinator is used to show the aircraft's rate of turn—how fast it's changing direction. A mechanism in the turn coordinator is oriented such that when the airplane turns on the vertical axis it forces the miniature airplane on the TC to turn.

The Turn Coordinator (TC) – 2 of 10



The Turn Coordinator (TC) – 3 of 10



The rate of movement makes the TC's miniature airplane lean to the left or right.

The Turn Coordinator (TC) – 4 of 10



The Turn Coordinator (TC) – 5 of 10

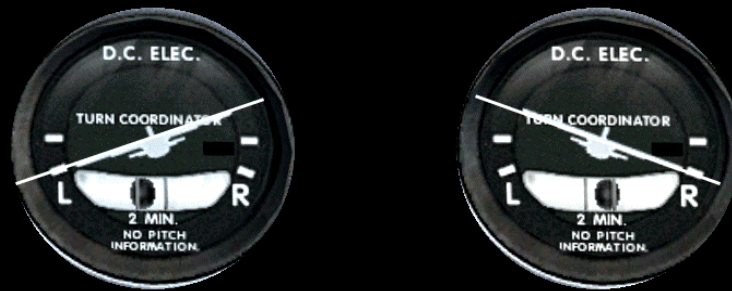


When the wings of the miniature airplane align with the lines next to the "L" and "R," the aircraft is making a standard rate turn:

Standard rate turn
to the left

Standard rate turn
to the right

The Turn Coordinator (TC) – 6 of 10

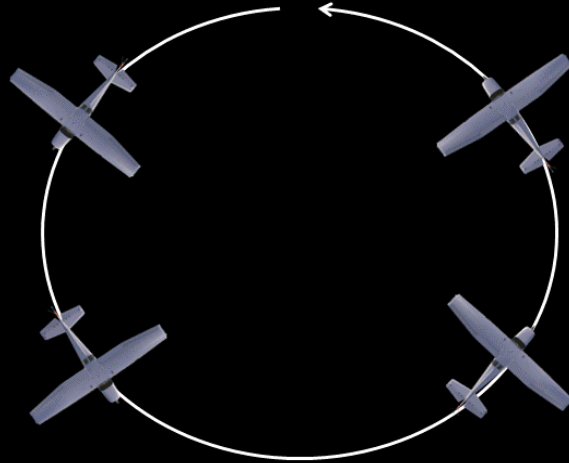


The Turn Coordinator (TC) – 7 of 10



A standard rate turn indicates that the aircraft completes a 360-degree turn in two minutes.

The Turn Coordinator (TC) – 8 of 10



The Turn Coordinator (TC) – 9 of 10



The faster the turn, the greater the movement, and the steeper the lean of the TC's miniature airplane:

Standard rate turn
to the left

Steep turn to
the right

The Turn Coordinator (TC) – 10 of 10



The Heading Indicator (HI) – 1 of 8



The heading indicator is sometimes called the “compass card.” The HI provides a smooth and precise indication of heading or turns as a result of yaw movement.

The Heading Indicator (HI) – 2 of 8



The Heading Indicator (HI) – 3 of 8



A card in the HI that is marked with heading degrees maintains its orientation as the actual airplane turns. Thus, the miniature airplane at the center of the HI always remains pointing upward, only this heading card rotates.

The Heading Indicator (HI) – 4 of 8



The Heading Indicator (HI) – 5 of 8



The card in the HI is marked off with numbers every 30 degrees and the cardinal directions indicated by N (North), S (South), E (East), W (West).

The Heading Indicator (HI) – 6 of 8



The Heading Indicator (HI) – 7 of 8



To read the numbers on the HI, simply “add” a zero. For example:

The HI is pointing to the “6,” which indicates a “60 degrees” heading

The HI is pointing to the “21,” which indicates a “210 degrees” heading

The Heading Indicator (HI) – 8 of 8



Pitot-Static Instruments



A Pitot-static system consists of a system of pressure-sensitive instruments and the means by which the appropriate pressures are obtained

The Pitot-static instruments provide the pilot with information regarding speed (top left), altitude (top right), and rate of climb or descent (bottom right).

Please, access the links below to learn about each instrument



[Airspeed Indicator](#)



[Altimeter](#)



[Vertical Speed Indicator](#)

The Airspeed Indicator (ASI) – 1 of 4



This airspeed indicator is calibrated in knots. The ASI is divided into color-coded arcs that define speed ranges for different phases of flight: for use of flaps (white), for normal operations (green), for smooth air operations or caution speed (yellow), and for maximum or “never-exceed” speed (red).

The Airspeed Indicator (ASI) – 2 of 4



The Airspeed Indicator (ASI) – 3 of 4



The ASI displays changes in the forward movement of the airplane:

The ASI indicates a speed of 80 knots

The ASI indicates a speed of 120 knots

The Airspeed Indicator (ASI) – 4 of 4



The Altimeter – 1 of 6



The altimeter displays changes in the vertical movement (up and down) of the airplane.

The Altimeter – 2 of 6



The Altimeter – 3 of 6



The altimeter usually has two pointers to indicate the airplanes' altitude. These pointers are generally arranged as follows:

A pointer with a flared triangular tip showing 1,000 foot intervals

A pointer with a needle tip showing 100 feet intervals

The Altimeter – 4 of 6



The Altimeter – 5 of 6



The altimeter is numbered 0 through 9. How to read the altitude on the example below:

First read the flared triangular tip. Here it rests between 2 and 3 (indicating an altitude above 2,000 feet)

Second, read the needle tip. Here it rests between 7 and 8 (indicating an at least 700 feet). Actually, it is $\frac{3}{5}$ th of the way to 8, indicating 760 feet.

Finally, add the two values. Here we have $2,000 + 760$ indicating an altitude of 2,760

The Altimeter – 6 of 6

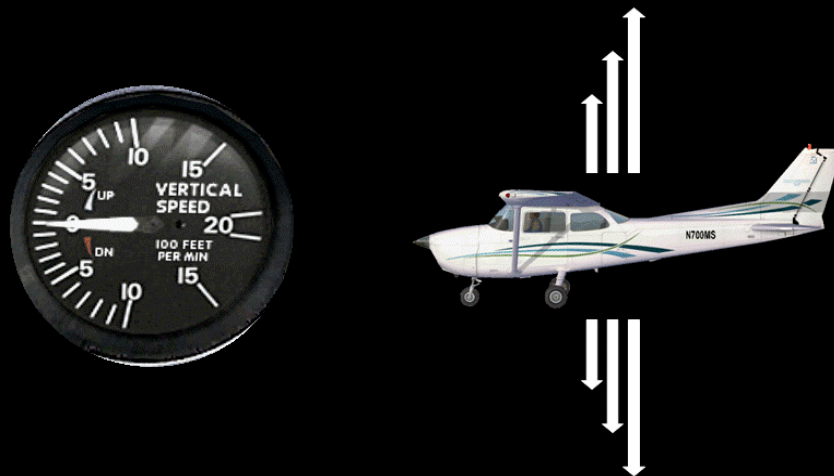


The Vertical Speed Indicator (VSI) – 1 of 4



The vertical speed indicator displays changes in the vertical rate of movement of the airplane when it climbs or descends, that is, how fast it goes up or down.

The Vertical Speed Indicator (VSI) – 2 of 4



The Vertical Speed Indicator (VSI) – 3 of 4



The VSI is calibrated in 100 feet per minute intervals. To read the VSI, first determine if the needle lays up or down. Above “0” indicates a climb and below “0” indicates a descent, and then gauge the speed of the ascent/descent

Here the VSI shows a rate of climb of 500 feet per minute.

The Vertical Speed Indicator (VSI) – 4 of 4



End of Training Tutorial



- This is the end of your training on the principles of flight
- Please feel free to review any concepts that you have not mastered
- Keep in mind that you will be tested later
- To terminate the training tutorial press the “Terminate Tutorial” button below

**TERMINATE
TUTORIAL**

APPENDIX D:
CBT CONCEPTS, CATEGORIES, AND FREQUENCY COUNT

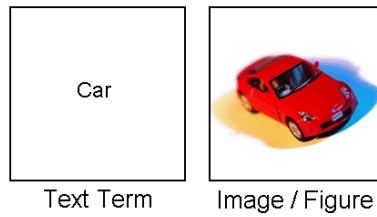
CONCEPT CATEGORY	CONCEPT	FREQUENCY COUNT
Airplane moving surface parts	Ailerons	5
Airplane moving surface parts	Elevators	4
Airplane moving surface parts	Horizontal stabilizer	1
Airplane moving surface parts	Rudder	5
Airplane moving surface parts	Vertical stabilizer	1
Axes of flight	Center of gravity	4
Axes of flight	Lateral axis	3
Axes of flight	Longitudinal axis	5
Axes of flight	Three axis of flight	1
Axes of flight	Vertical axis	4
Gyroscopic instruments	Aircraft's attitude	1
Gyroscopic instruments	Attitude Indicator	6
Gyroscopic instruments	Cardinal directions	1
Gyroscopic instruments	Compass card	1
Gyroscopic instruments	Gyroscope	1
Gyroscopic instruments	Gyroscoping instruments	1
Gyroscopic instruments	Heading card	1
Gyroscopic instruments	Heading degrees	1
Gyroscopic instruments	Heading indicator	4
Gyroscopic instruments	Indication or heading	1
Gyroscopic instruments	Miniature airplane	5
Gyroscopic instruments	Standard rate turn	2
Gyroscopic instruments	True horizon	2
Gyroscopic instruments	Turn coordinator	3
Movement	100 feet per minute	1
Movement	Bank	2
Movement	Changes in vertical rate	1
Movement	Climb	3
Movement	Descend	3
Movement	Pitch	2
Movement	vertical movement	1
Movement	Yaw	3
Pitot-static instruments	"Never-exceed" speed	1
Pitot-static instruments	Airspeed indicator	2
Pitot-static instruments	Altimeter	3
Pitot-static instruments	caution speed	1
Pitot-static instruments	Flaps	1
Pitot-static instruments	Flared triangular tip	2
Pitot-static instruments	Knots	1
Pitot-static instruments	Needle tip	2
Pitot-static instruments	Normal operations	1
Pitot-static instruments	Pitot-static instruments	1
Pitot-static instruments	Vertical speed indicator	2

APPENDIX E:
RC1 TEST

Slide 1

INSTRUCTIONS

In this exercise you are asked to respond as fast as you can regarding the relationship of the text term and the image / figure. Below is an example of what one of each looks like:



Click on the **SPACEBAR** to proceed

Slide 2

INSTRUCTIONS

There are two possible responses:

Press the specially labeled “**S**” key on the keyboard if the text term and the image / figure represent the **SAME** concept

Press the specially labeled “**D**” key on the keyboard if the text term and the image / figure represent a **DIFFERENT** concept



Click on the **SPACEBAR** to proceed

Slide 3

INSTRUCTIONS

It is very important that you try to be as quick as possible when making a decision. follow your 'gut' feeling rather than spending time 'thinking' about the correct answer. However, both your response time and accuracy will be recorded. That is, even though you are asked to be as quick as possible, your performance will be evaluated.

Once you choose your response you will not be able to go back. Next, you will familiarize yourself with the specially labeled keys and practice on four sample items. Only the first item will reiterate your response choices.

Click on the SPACEBAR to proceed

Slide 4

INSTRUCTIONS

Press the specially labeled "**S**" key on the keyboard **NOW**



Slide 5

INSTRUCTIONS

Thank you!



Slide 6

INSTRUCTIONS

Press the specially labeled "D"
key on the keyboard **NOW**



Slide 7

INSTRUCTIONS

Thank you!

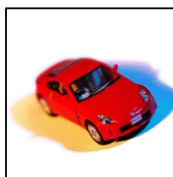
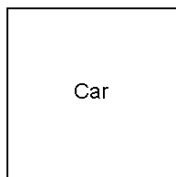


Slide 8

INSTRUCTIONS

Press the specially labeled key 'S' if the text and image / figure concepts are the same

Press the specially labeled key 'D' if the text and image / figure concepts are different



Slide 9

Boat



Slide 10

Wheel



Slide 11

Police
Car



Slide 12

INSTRUCTIONS SUMMARY

- You are asked to respond as fast as you can regarding the relationship of the text term and the image / figure
- It is important that you try to respond quickly
- Press the specially labeled key 'S' if the concepts are the same, or 'D' if they are different
- Once you have chosen your response you will not be able to go back to change it
- Overall, there are just over 100 items to respond to

When you are ready press the SPACEBAR and the test will begin

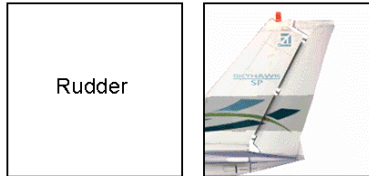
Slide 13

CORRECT

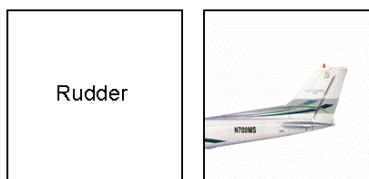
Slide 14

INCORRECT

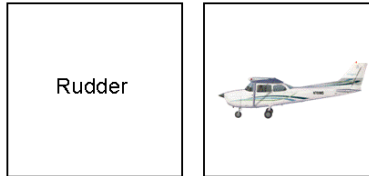
Slide 15



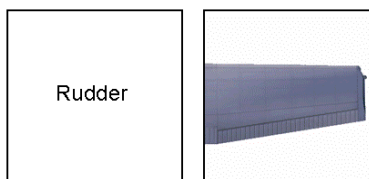
Slide 16



Slide 17



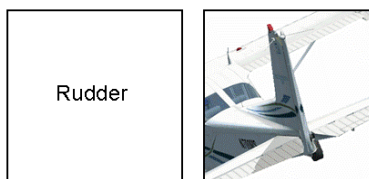
Slide 18



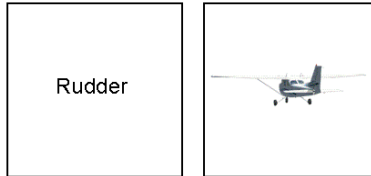
Slide 19



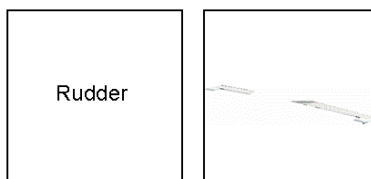
Slide 20



Slide 21

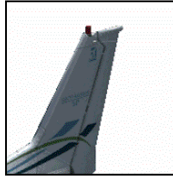


Slide 22



Slide 23

Rudder



Slide 24

Rudder



Slide 25

Rudder

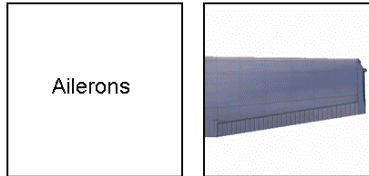


Slide 26

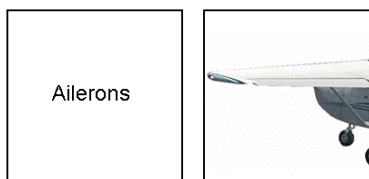
Rudder



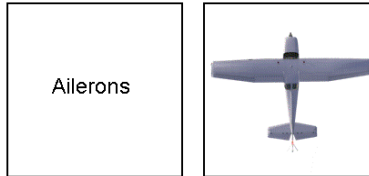
Slide 27



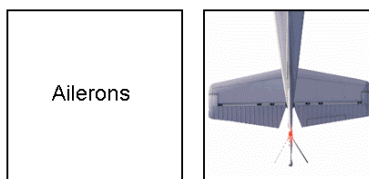
Slide 28



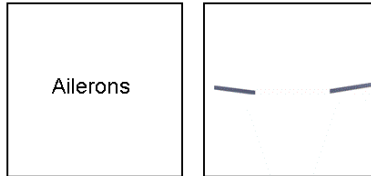
Slide 29



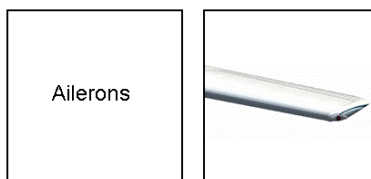
Slide 30



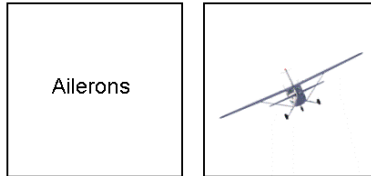
Slide 31



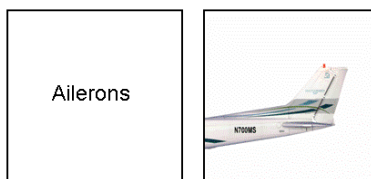
Slide 32



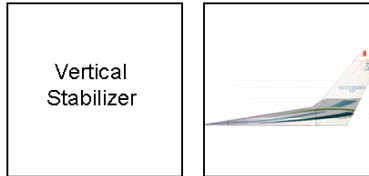
Slide 33



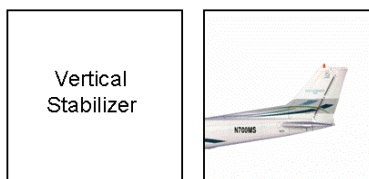
Slide 34



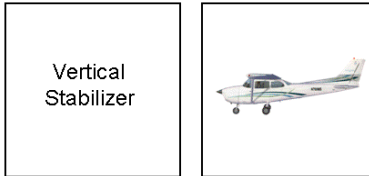
Slide 35



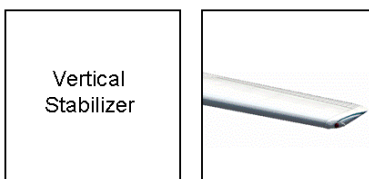
Slide 36



Slide 37

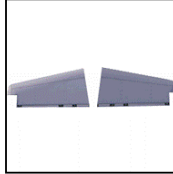


Slide 38



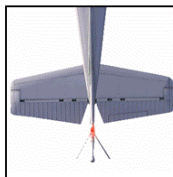
Slide 39

Horizontal
Stabilizer



Slide 40

Horizontal
Stabilizer



Slide 41

Horizontal
Stabilizer

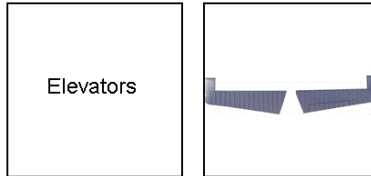


Slide 42

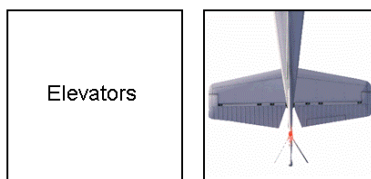
Horizontal
Stabilizer



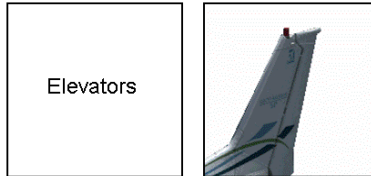
Slide 43



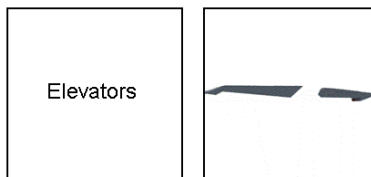
Slide 44



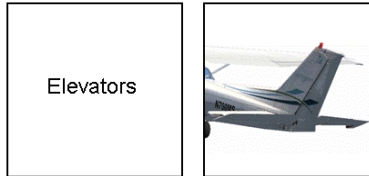
Slide 45



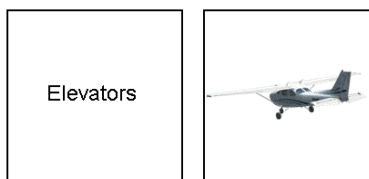
Slide 46



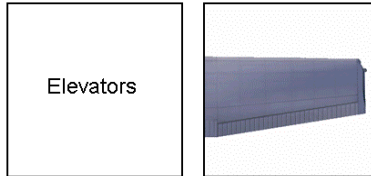
Slide 47



Slide 48



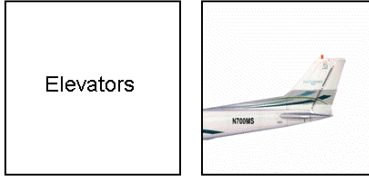
Slide 49



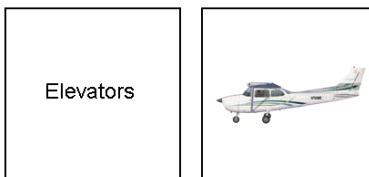
Slide 50



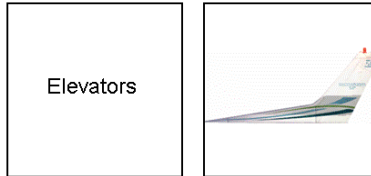
Slide 51



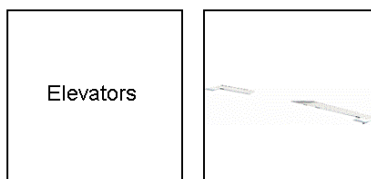
Slide 52



Slide 53



Slide 54



Slide 55

Elevators

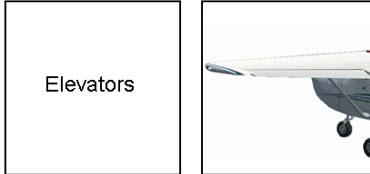


Slide 56

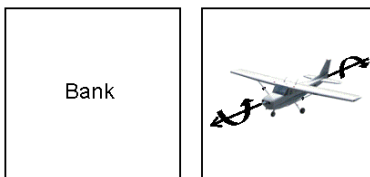
Elevators



Slide 57



Slide 58



Slide 59

Bank

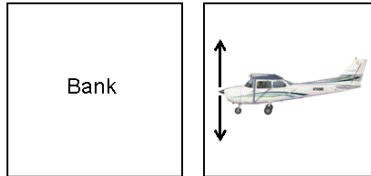


Slide 60

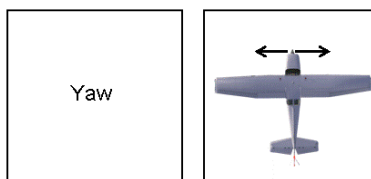
Bank



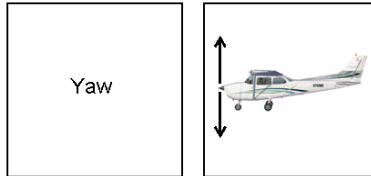
Slide 61



Slide 62



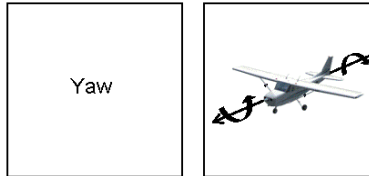
Slide 63



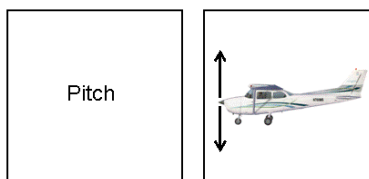
Slide 64



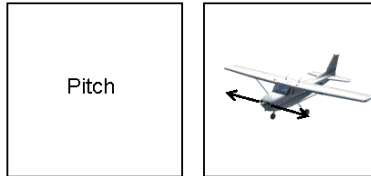
Slide 65



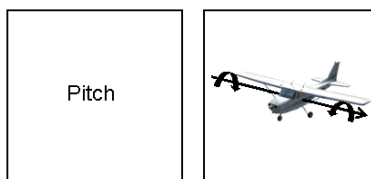
Slide 66



Slide 67



Slide 68



Slide 69

Pitch



Slide 70

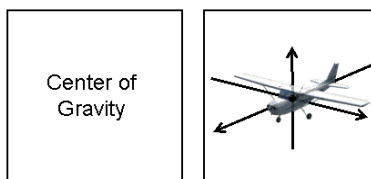
Center of Gravity



Slide 71



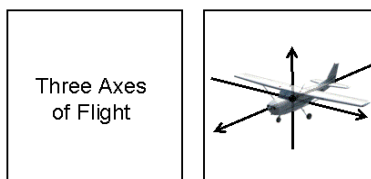
Slide 72



Slide 73



Slide 74



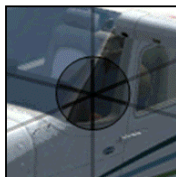
Slide 75

Three Axes
of Flight



Slide 76

Three Axes
of Flight



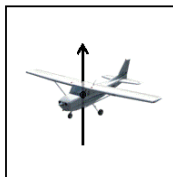
Slide 77

Three Axes
of Flight

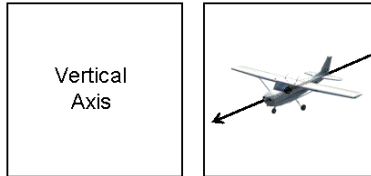


Slide 78

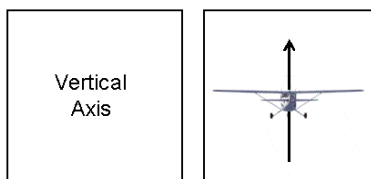
Vertical
Axis



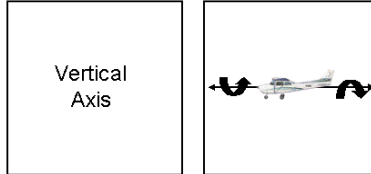
Slide 79



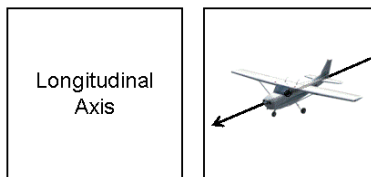
Slide 80



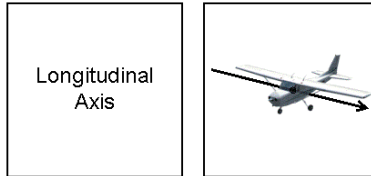
Slide 81



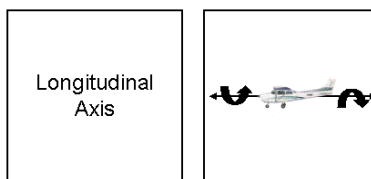
Slide 82



Slide 83



Slide 84



Slide 85

Longitudinal
Axis

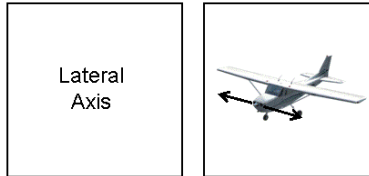


Slide 86

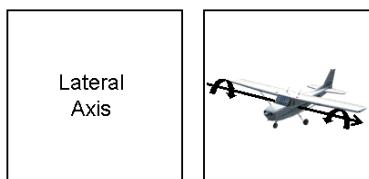
Lateral
Axis



Slide 87



Slide 88



Slide 89

Lateral
Axis



Slide 90

Gyroscopic
Instruments



Slide 91

Gyroscopic
Instruments



Slide 92

Attitude
Indicator



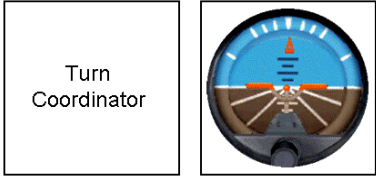
Slide 93



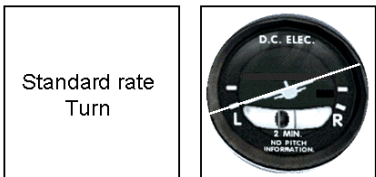
Slide 94



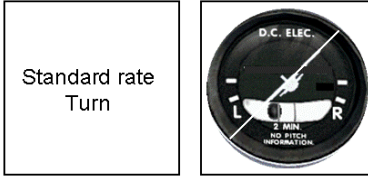
Slide 95



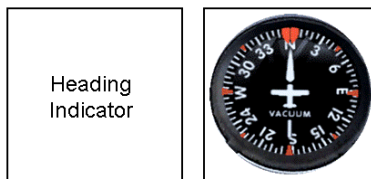
Slide 96



Slide 97



Slide 98



Slide 99



Slide 100



Slide 101

Pitot-static
Instruments

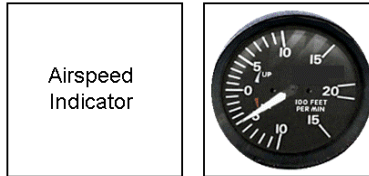


Slide 102

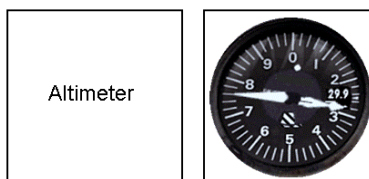
Airspeed
Indicator



Slide 103



Slide 104

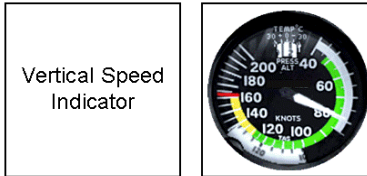


Slide 105



Slide 106





APPENDIX F:
RC1 CAR TEST

Slide 1

TEST COMPLETE!

You will now be asked to complete a short test (12 items) with the same rules as the one you have just completed. The only difference is that the items are from the automotive industry.

When you are ready press the SPACEBAR and the short test will begin

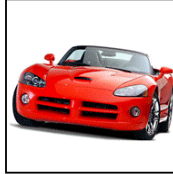
Slide 2

Alfa Romeo
8C



Slide 3

Alfa Romeo
8C



Slide 4

Dodge Viper



Slide 5

Dodge Viper



Slide 6

Honda Fit



Slide 7



Slide 8



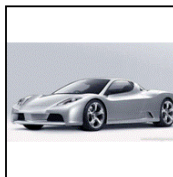
Slide 9

FIAT 500



Slide 10

Honda NSX



Slide 11

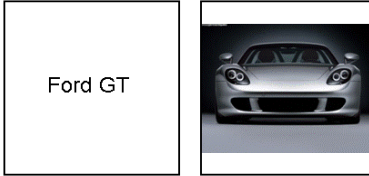
Honda NSX



Slide 12

Ford GT



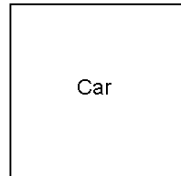


APPENDIX G:
RC2 TEST

Slide 1

INSTRUCTIONS

In this exercise you are asked to indicate the degree to which the text term and the image / figure are related. Below is an example of what one of each looks like:



Text Term

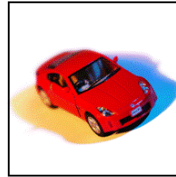


Image / Figure

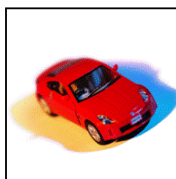
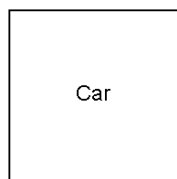
You can choose the degree of relatedness on a scale that ranges from 1 (no relationship) to 5 (highly related). When you choose your response, it is essential that you try to respond as quickly as possible. It is very important that you follow your 'gut' feeling rather than spending time choosing the strength of a relationship. However, both your response time and accuracy will be recorded.

Once you choose your response you will not be able to go back. Next, you will practice on three sample items. Click on continue (bottom right of the screen) to proceed.

Slide 2

INSTRUCTIONS

Indicate, as fast as you can, the degree to which the term and the image / figure are related:

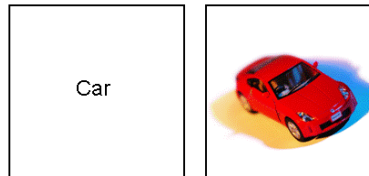


<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
1	2	3	4	5
Not Related		Moderately Related		Highly Related

Slide 3

INSTRUCTIONS

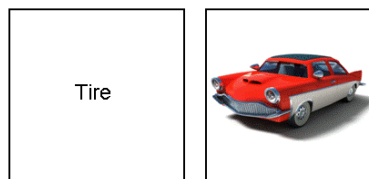
In this case the text term accurately reflects the image / figure; therefore, 4 or 5 are acceptable choices



Slide 4

INSTRUCTIONS

Indicate, as fast as you can, the degree to which the term and the image / figure are related:

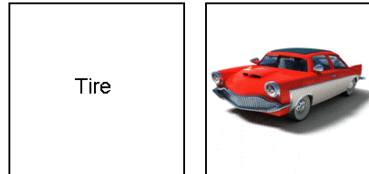


- | | | | | |
|-------------|---|--------------------|---|----------------|
| 1 | 2 | 3 | 4 | 5 |
| Not Related | | Moderately Related | | Highly Related |

Slide 5

INSTRUCTIONS

In this case the text term is represented but not specific to the image / figure; therefore, anywhere from 2 to 4 is acceptable



Slide 6

INSTRUCTIONS

Indicate, as fast as you can, the degree to which the term and the image / figure are related:



Slide 7

INSTRUCTIONS

In this case the text term is not represented at all in the image / figure; therefore, 1 is an acceptable choice



Slide 8

INSTRUCTIONS

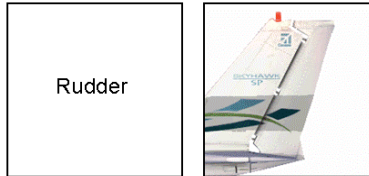
- You are asked to indicate the degree to which the text term and the image / figure are related
- It is important that you try to respond quickly
- Test items may be completely, moderately, or not related at all
- Once you have chosen your response you will not be able to go back to change it
- Overall, there are 47 items to respond to

When you are ready click on continue and the test will begin

Slide 9

INSTRUCTIONS

Indicate, as fast as you can, the degree to which the term and the image / figure are related:

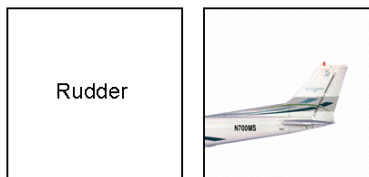


- | | | | | |
|-------------|---|--------------------|---|----------------|
| 1 | 2 | 3 | 4 | 5 |
| Not Related | | Moderately Related | | Highly Related |

Slide 10

INSTRUCTIONS

Indicate, as fast as you can, the degree to which the term and the image / figure are related:

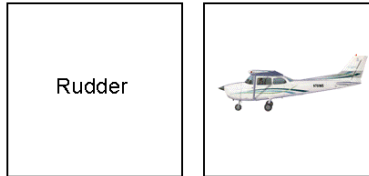


- | | | | | |
|-------------|---|--------------------|---|----------------|
| 1 | 2 | 3 | 4 | 5 |
| Not Related | | Moderately Related | | Highly Related |

Slide 11

INSTRUCTIONS

Indicate, as fast as you can, the degree to which the term and the image / figure are related:

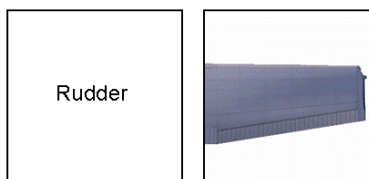


- | | | | | |
|-------------|---|--------------------|---|----------------|
| 1 | 2 | 3 | 4 | 5 |
| Not Related | | Moderately Related | | Highly Related |

Slide 12

INSTRUCTIONS

Indicate, as fast as you can, the degree to which the term and the image / figure are related:

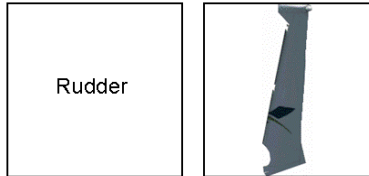


- | | | | | |
|-------------|---|--------------------|---|----------------|
| 1 | 2 | 3 | 4 | 5 |
| Not Related | | Moderately Related | | Highly Related |

Slide 13

INSTRUCTIONS

Indicate, as fast as you can, the degree to which the term and the image / figure are related:

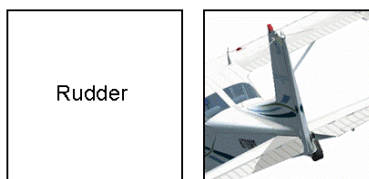


- 1
Not
Related
- 2
- 3
Moderately
Related
- 4
- 5
Highly
Related

Slide 14

INSTRUCTIONS

Indicate, as fast as you can, the degree to which the term and the image / figure are related:

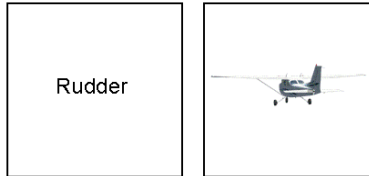


- 1
Not
Related
- 2
- 3
Moderately
Related
- 4
- 5
Highly
Related

Slide 15

INSTRUCTIONS

Indicate, as fast as you can, the degree to which the term and the image / figure are related:

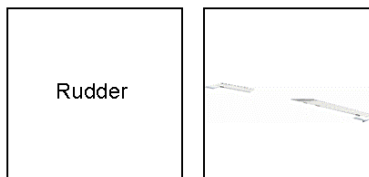


- | | | | | |
|-------------|---|--------------------|---|----------------|
| 1 | 2 | 3 | 4 | 5 |
| Not Related | | Moderately Related | | Highly Related |

Slide 16

INSTRUCTIONS

Indicate, as fast as you can, the degree to which the term and the image / figure are related:



- | | | | | |
|-------------|---|--------------------|---|----------------|
| 1 | 2 | 3 | 4 | 5 |
| Not Related | | Moderately Related | | Highly Related |

Slide 17

INSTRUCTIONS

Indicate, as fast as you can, the degree to which the term and the image / figure are related:



- | | | | | |
|-------------|---|--------------------|---|----------------|
| 1 | 2 | 3 | 4 | 5 |
| Not Related | | Moderately Related | | Highly Related |

Slide 18

INSTRUCTIONS

Indicate, as fast as you can, the degree to which the term and the image / figure are related:



- | | | | | |
|-------------|---|--------------------|---|----------------|
| 1 | 2 | 3 | 4 | 5 |
| Not Related | | Moderately Related | | Highly Related |

Slide 19

INSTRUCTIONS

Indicate, as fast as you can, the degree to which the term and the image / figure are related:

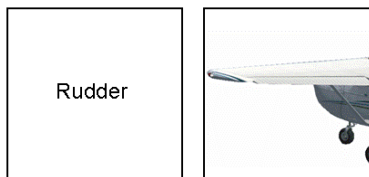


- | | | | | |
|-------------|---|--------------------|---|----------------|
| 1 | 2 | 3 | 4 | 5 |
| Not Related | | Moderately Related | | Highly Related |

Slide 20

INSTRUCTIONS

Indicate, as fast as you can, the degree to which the term and the image / figure are related:

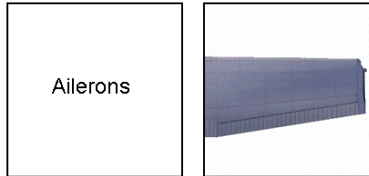


- | | | | | |
|-------------|---|--------------------|---|----------------|
| 1 | 2 | 3 | 4 | 5 |
| Not Related | | Moderately Related | | Highly Related |

Slide 21

INSTRUCTIONS

Indicate, as fast as you can, the degree to which the term and the image / figure are related:

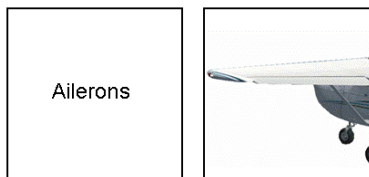


1	2	3	4	5
Not Related		Moderately Related		Highly Related

Slide 22

INSTRUCTIONS

Indicate, as fast as you can, the degree to which the term and the image / figure are related:

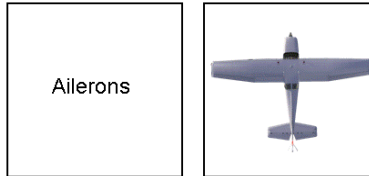


1	2	3	4	5
Not Related		Moderately Related		Highly Related

Slide 23

INSTRUCTIONS

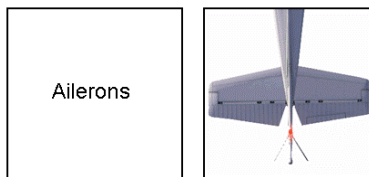
Indicate, as fast as you can, the degree to which the term and the image / figure are related:



Slide 24

INSTRUCTIONS

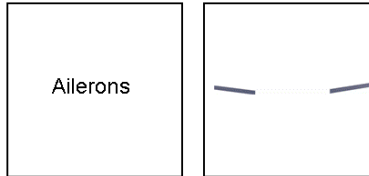
Indicate, as fast as you can, the degree to which the term and the image / figure are related:



Slide 25

INSTRUCTIONS

Indicate, as fast as you can, the degree to which the term and the image / figure are related:

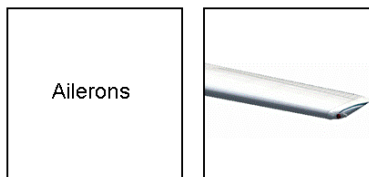


- 1
Not
Related
- 2
- 3
Moderately
Related
- 4
- 5
Highly
Related

Slide 26

INSTRUCTIONS

Indicate, as fast as you can, the degree to which the term and the image / figure are related:

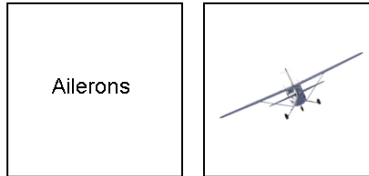


- 1
Not
Related
- 2
- 3
Moderately
Related
- 4
- 5
Highly
Related

Slide 27

INSTRUCTIONS

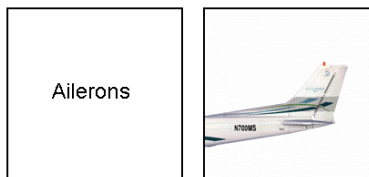
Indicate, as fast as you can, the degree to which the term and the image / figure are related:



Slide 28

INSTRUCTIONS

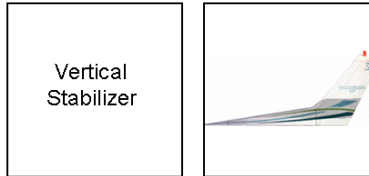
Indicate, as fast as you can, the degree to which the term and the image / figure are related:



Slide 29

INSTRUCTIONS

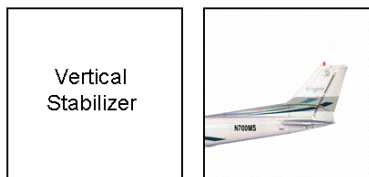
Indicate, as fast as you can, the degree to which the term and the image / figure are related:



Slide 30

INSTRUCTIONS

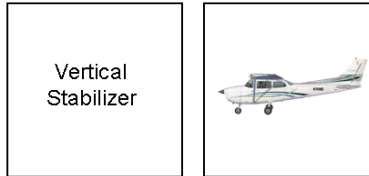
Indicate, as fast as you can, the degree to which the term and the image / figure are related:



Slide 31

INSTRUCTIONS

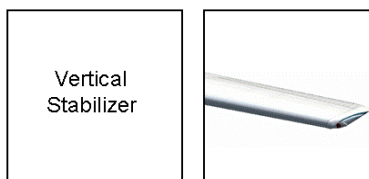
Indicate, as fast as you can, the degree to which the term and the image / figure are related:



Slide 32

INSTRUCTIONS

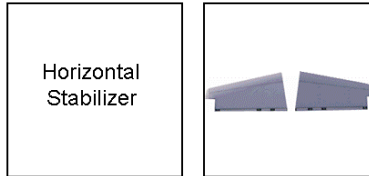
Indicate, as fast as you can, the degree to which the term and the image / figure are related:



Slide 33

INSTRUCTIONS

Indicate, as fast as you can, the degree to which the term and the image / figure are related:

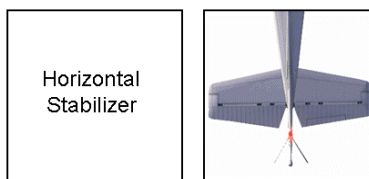


- 1
Not Related
- 2
- 3
Moderately Related
- 4
- 5
Highly Related

Slide 34

INSTRUCTIONS

Indicate, as fast as you can, the degree to which the term and the image / figure are related:

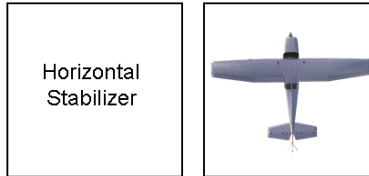


- 1
Not Related
- 2
- 3
Moderately Related
- 4
- 5
Highly Related

Slide 35

INSTRUCTIONS

Indicate, as fast as you can, the degree to which the term and the image / figure are related:

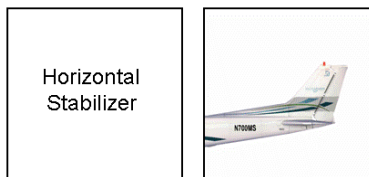


- | | | | | |
|-------------|---|--------------------|---|----------------|
| 1 | 2 | 3 | 4 | 5 |
| Not Related | | Moderately Related | | Highly Related |

Slide 36

INSTRUCTIONS

Indicate, as fast as you can, the degree to which the term and the image / figure are related:

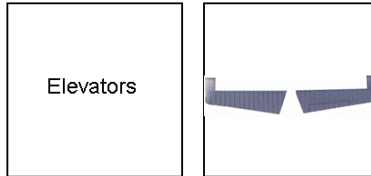


- | | | | | |
|-------------|---|--------------------|---|----------------|
| 1 | 2 | 3 | 4 | 5 |
| Not Related | | Moderately Related | | Highly Related |

Slide 37

INSTRUCTIONS

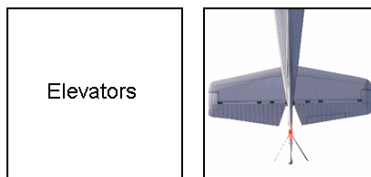
Indicate, as fast as you can, the degree to which the term and the image / figure are related:



Slide 38

INSTRUCTIONS

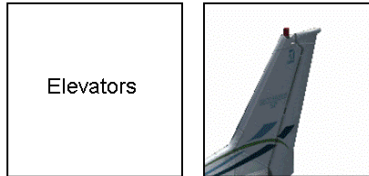
Indicate, as fast as you can, the degree to which the term and the image / figure are related:



Slide 39

INSTRUCTIONS

Indicate, as fast as you can, the degree to which the term and the image / figure are related:

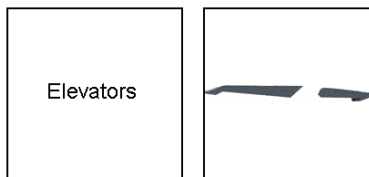


- | | | | | |
|-------------|---|--------------------|---|----------------|
| 1 | 2 | 3 | 4 | 5 |
| Not Related | | Moderately Related | | Highly Related |

Slide 40

INSTRUCTIONS

Indicate, as fast as you can, the degree to which the term and the image / figure are related:

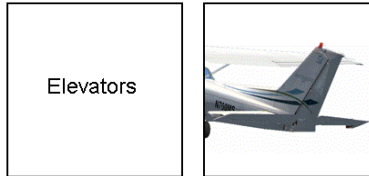


- | | | | | |
|-------------|---|--------------------|---|----------------|
| 1 | 2 | 3 | 4 | 5 |
| Not Related | | Moderately Related | | Highly Related |

Slide 41

INSTRUCTIONS

Indicate, as fast as you can, the degree to which the term and the image / figure are related:

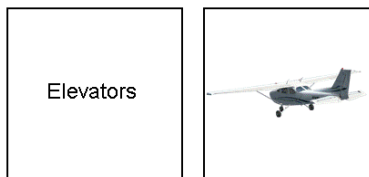


- | | | | | |
|-------------|---|--------------------|---|----------------|
| 1 | 2 | 3 | 4 | 5 |
| Not Related | | Moderately Related | | Highly Related |

Slide 42

INSTRUCTIONS

Indicate, as fast as you can, the degree to which the term and the image / figure are related:

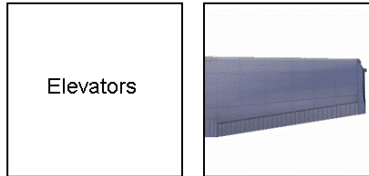


- | | | | | |
|-------------|---|--------------------|---|----------------|
| 1 | 2 | 3 | 4 | 5 |
| Not Related | | Moderately Related | | Highly Related |

Slide 43

INSTRUCTIONS

Indicate, as fast as you can, the degree to which the term and the image / figure are related:

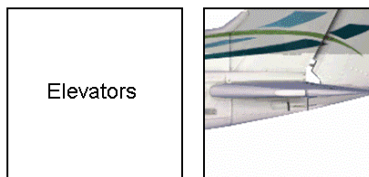


1	2	3	4	5
Not Related		Moderately Related		Highly Related

Slide 44

INSTRUCTIONS

Indicate, as fast as you can, the degree to which the term and the image / figure are related:

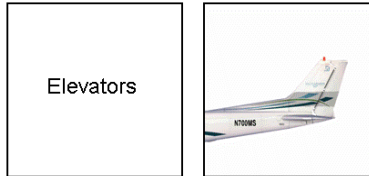


1	2	3	4	5
Not Related		Moderately Related		Highly Related

Slide 45

INSTRUCTIONS

Indicate, as fast as you can, the degree to which the term and the image / figure are related:

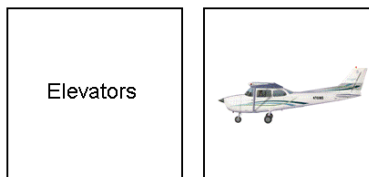


- | | | | | |
|----------------|---|-----------------------|---|-------------------|
| 1 | 2 | 3 | 4 | 5 |
| Not
Related | | Moderately
Related | | Highly
Related |

Slide 46

INSTRUCTIONS

Indicate, as fast as you can, the degree to which the term and the image / figure are related:

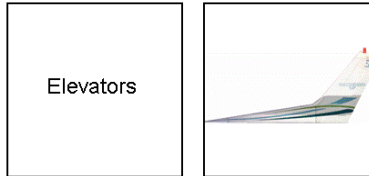


- | | | | | |
|----------------|---|-----------------------|---|-------------------|
| 1 | 2 | 3 | 4 | 5 |
| Not
Related | | Moderately
Related | | Highly
Related |

Slide 47

INSTRUCTIONS

Indicate, as fast as you can, the degree to which the term and the image / figure are related:

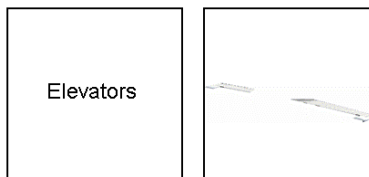


1	2	3	4	5
Not Related		Moderately Related		Highly Related

Slide 48

INSTRUCTIONS

Indicate, as fast as you can, the degree to which the term and the image / figure are related:



1	2	3	4	5
Not Related		Moderately Related		Highly Related

Slide 49

INSTRUCTIONS

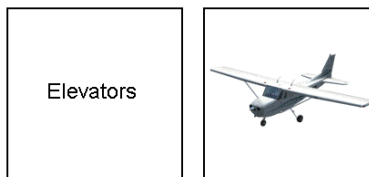
Indicate, as fast as you can, the degree to which the term and the image / figure are related:



Slide 50

INSTRUCTIONS

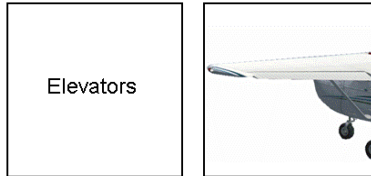
Indicate, as fast as you can, the degree to which the term and the image / figure are related:



Slide 51

INSTRUCTIONS

Indicate, as fast as you can, the degree to which the term and the image / figure are related:

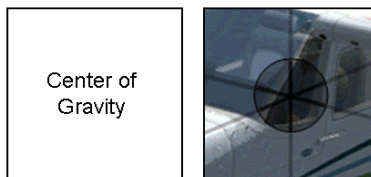


- | | | | | |
|----------------|---|-----------------------|---|-------------------|
| 1 | 2 | 3 | 4 | 5 |
| Not
Related | | Moderately
Related | | Highly
Related |

Slide 52

INSTRUCTIONS

Indicate, as fast as you can, the degree to which the term and the image / figure are related:



- | | | | | |
|----------------|---|-----------------------|---|-------------------|
| 1 | 2 | 3 | 4 | 5 |
| Not
Related | | Moderately
Related | | Highly
Related |

Slide 53

INSTRUCTIONS

Indicate, as fast as you can, the degree to which the term and the image / figure are related:

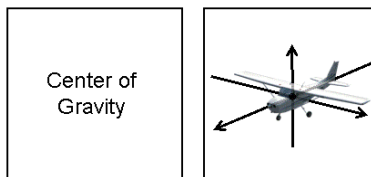


- 1
Not Related
- 2
- 3
Moderately Related
- 4
- 5
Highly Related

Slide 54

INSTRUCTIONS

Indicate, as fast as you can, the degree to which the term and the image / figure are related:



- 1
Not Related
- 2
- 3
Moderately Related
- 4
- 5
Highly Related

Slide 55

INSTRUCTIONS

Indicate, as fast as you can, the degree to which the term and the image / figure are related:



1	2	3	4	5
Not Related		Moderately Related		Highly Related

APPENDIX H:
RC2 CAR TEST

Slide 1

TEST COMPLETE!


You will now be asked to complete a short test (12 items) with the same rules as the one you have just completed. The only difference is that the items are from the automotive industry.

When you are ready click on continue and the short test will begin

Slide 2

INSTRUCTIONS

Indicate, as fast as you can, the degree to which the term and the image / figure are related:

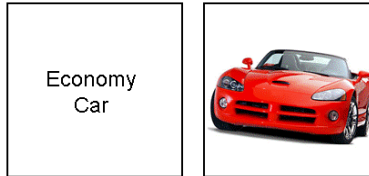
Exotic Car	
------------	---

1	2	3	4	5
Not Related		Moderately Related		Highly Related

Slide 3

INSTRUCTIONS

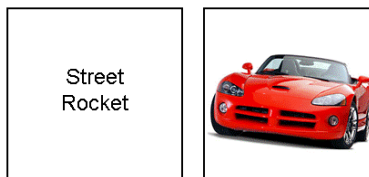
Indicate, as fast as you can, the degree to which the term and the image / figure are related:



Slide 4

INSTRUCTIONS

Indicate, as fast as you can, the degree to which the term and the image / figure are related:



Slide 5

INSTRUCTIONS

Indicate, as fast as you can, the degree to which the term and the image / figure are related:



Slide 6

INSTRUCTIONS

Indicate, as fast as you can, the degree to which the term and the image / figure are related:



Slide 7

INSTRUCTIONS

Indicate, as fast as you can, the degree to which the term and the image / figure are related:



Slide 8

INSTRUCTIONS

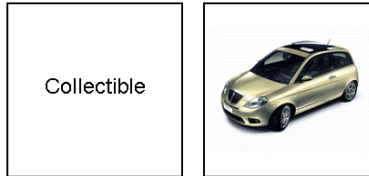
Indicate, as fast as you can, the degree to which the term and the image / figure are related:



Slide 9

INSTRUCTIONS

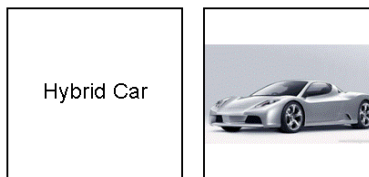
Indicate, as fast as you can, the degree to which the term and the image / figure are related:



Slide 10

INSTRUCTIONS

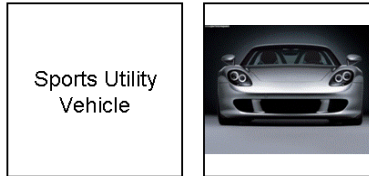
Indicate, as fast as you can, the degree to which the term and the image / figure are related:



Slide 11

INSTRUCTIONS

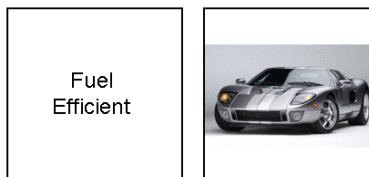
Indicate, as fast as you can, the degree to which the term and the image / figure are related:



Slide 12

INSTRUCTIONS

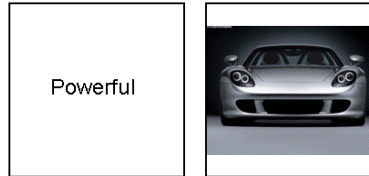
Indicate, as fast as you can, the degree to which the term and the image / figure are related:



Slide 13

INSTRUCTIONS

Indicate, as fast as you can, the degree to which the term and the image / figure are related:

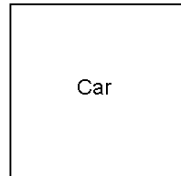


APPENDIX I:
RC3 TEST

Slide 1

INSTRUCTIONS

In this exercise you are asked to correctly identify which image or figure goes with a specific text term. Below is an example of what one of each looks like:



Text Term

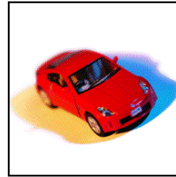


Image / Figure

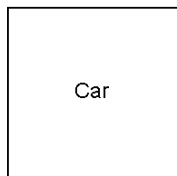
Most of the time you will be asked to pair the right image / figure with the text term. Sometimes it will be the other way around. When you choose your response, it is essential that you try to respond as quickly as possible. It is very important that you follow your 'gut' feeling rather than spending time finding the correct answer. Both your response time and accuracy will be recorded.

Test items can have one or more correct answers. In all cases always select what you feel is the most appropriate answer. Once you choose your response you will not be able to go back. Next, you will practice on two sample items. Click on continue (bottom right of the screen) to proceed.

Slide 2

INSTRUCTIONS

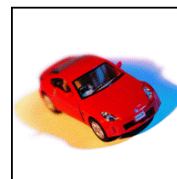
Select as fast as you can the most appropriate image / figure given the term:



A



C



B



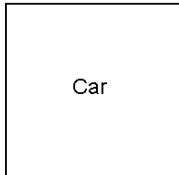
D



Slide 3

INSTRUCTIONS

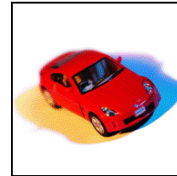
In this case A, B, and C were all correct, while D was not. Click on continue to try the next sample item.



A



C



B



D



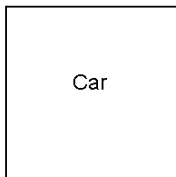
Slide 4

INSTRUCTIONS

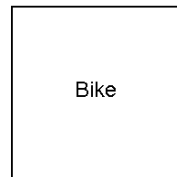
Select as fast as you can the most appropriate term given the image / figure :



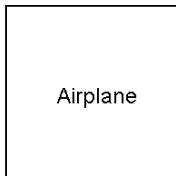
A



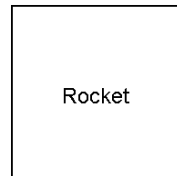
C



B



D



Slide 5

INSTRUCTIONS

In this case B was the only correct answer. Click on continue for a summary of instructions.



A

Car

C

Bike

B

Airplane

D

Rocket

Slide 6

INSTRUCTIONS

- You are asked to correctly identify which image or figure goes with a specific text term, or vice versa
- It is important that you try to respond quickly
- Test items have one or more correct answer. Choose the answer you feel is more appropriate.
- Once you have chosen your response you will not be able to go back to change it
- Overall, there are 46 items to respond to

When you are ready click on continue and the test will begin

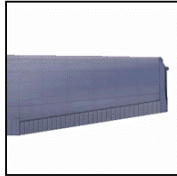
Slide 7

INSTRUCTIONS

Select as fast as you can the most appropriate image / figure given the term:

Rudder

A



C



B



D



Slide 8

INSTRUCTIONS

Select as fast as you can the most appropriate image / figure given the term:

Rudder

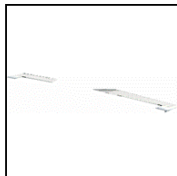
A



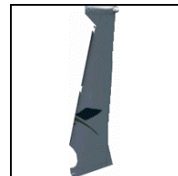
C



B



D



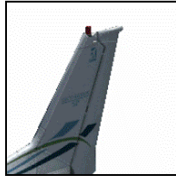
Slide 9

INSTRUCTIONS

Select as fast as you can the most appropriate image / figure given the term:

Rudder

A



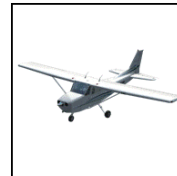
C



B



D



Slide 10

INSTRUCTIONS

Select as fast as you can the most appropriate image / figure given the term:

Ailerons

A



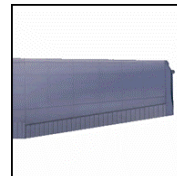
C



B



D



Slide 11

INSTRUCTIONS

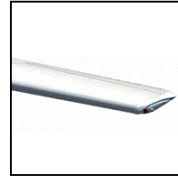
Select as fast as you can the most appropriate image / figure given the term:

Ailerons

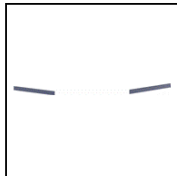
A



C



B



D



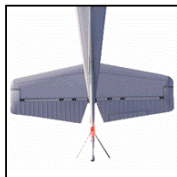
Slide 12

INSTRUCTIONS

Select as fast as you can the most appropriate image / figure given the term:

Ailerons

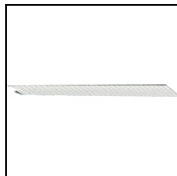
A



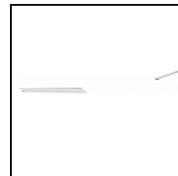
C



B



D



Slide 13

INSTRUCTIONS

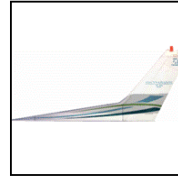
Select as fast as you can the most appropriate image / figure given the term:

Vertical
Stabilizer

A



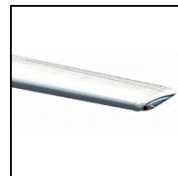
C



B



D



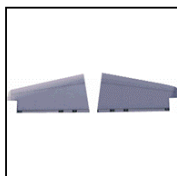
Slide 14

INSTRUCTIONS

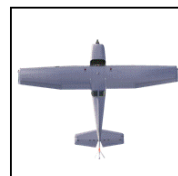
Select as fast as you can the most appropriate image / figure given the term:

Horizontal
Stabilizer

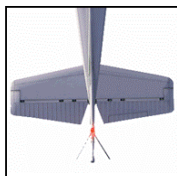
A



C



B



D



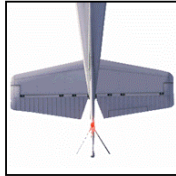
Slide 15

INSTRUCTIONS

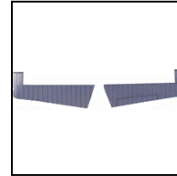
Select as fast as you can the most appropriate image / figure given the term:

Elevators

A



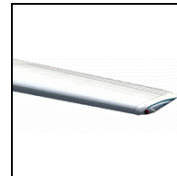
C



B



D



Slide 16

INSTRUCTIONS

Select as fast as you can the most appropriate image / figure given the term:

Elevators

A



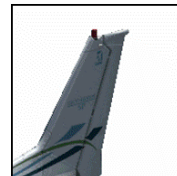
C



B



D



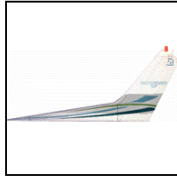
Slide 17

INSTRUCTIONS

Select as fast as you can the most appropriate image / figure given the term:

Elevators

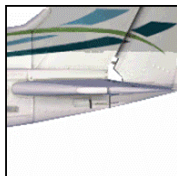
A



C



B



D



Slide 18

INSTRUCTIONS

Select as fast as you can the most appropriate image / figure given the term:

Elevators

A



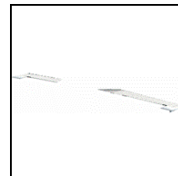
C



B



D



Slide 19

INSTRUCTIONS

Select as fast as you can the most appropriate image / figure given the term:

Bank

A



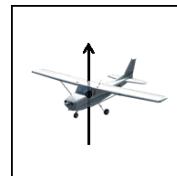
C



B



D



Slide 20

INSTRUCTIONS

Select as fast as you can the most appropriate image / figure given the term:

Bank

A



C



B



D



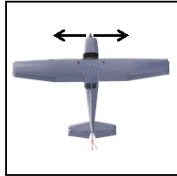
Slide 21

INSTRUCTIONS

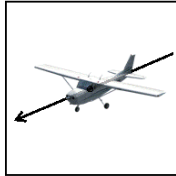
Select as fast as you can the most appropriate image / figure given the term:

Yaw

A



C



B



D



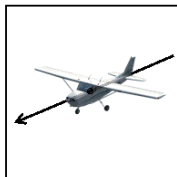
Slide 22

INSTRUCTIONS

Select as fast as you can the most appropriate image / figure given the term:

Yaw

A



C



B



D

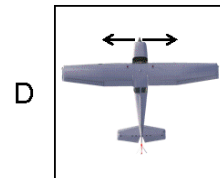
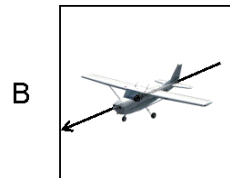
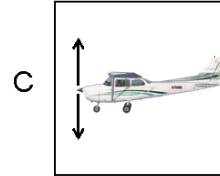


Slide 23

INSTRUCTIONS

Select as fast as you can the most appropriate image / figure given the term:

Pitch

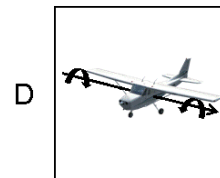
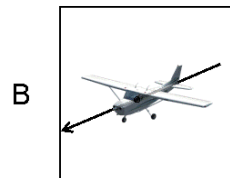
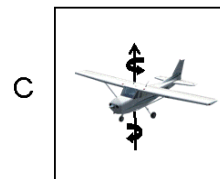
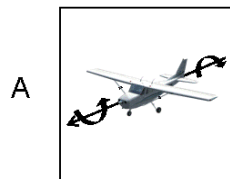


Slide 24

INSTRUCTIONS

Select as fast as you can the most appropriate image / figure given the term:

Pitch



Slide 25

INSTRUCTIONS

Select as fast as you can the most appropriate image / figure given the term:

Center of Gravity

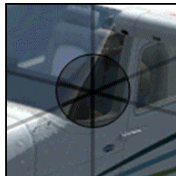
A



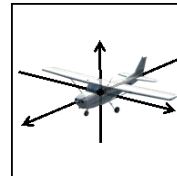
C



B



D



Slide 26

INSTRUCTIONS

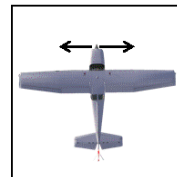
Select as fast as you can the most appropriate image / figure given the term:

Center of Gravity

A



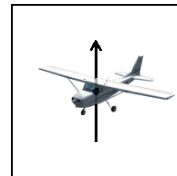
C



B



D



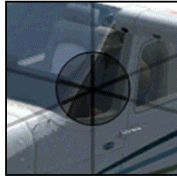
Slide 27

INSTRUCTIONS

Select as fast as you can the most appropriate image / figure given the term:

Three Axes
of Flight

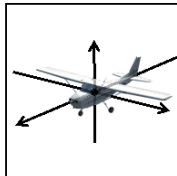
A



C



B



D



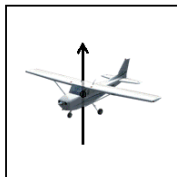
Slide 28

INSTRUCTIONS

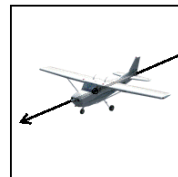
Select as fast as you can the most appropriate image / figure given the term:

Vertical
Axis

A



C



B



D



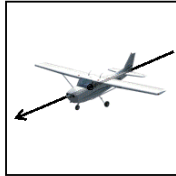
Slide 29

INSTRUCTIONS

Select as fast as you can the most appropriate image / figure given the term:

Vertical
Axis

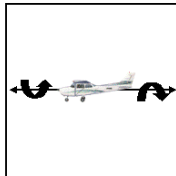
A



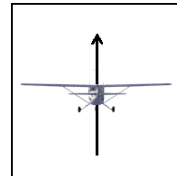
C



B



D



Slide 30

INSTRUCTIONS

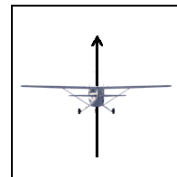
Select as fast as you can the most appropriate image / figure given the term:

Longitudinal
Axis

A



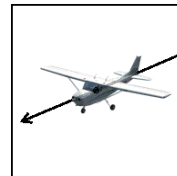
C



B



D



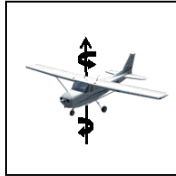
Slide 31

INSTRUCTIONS

Select as fast as you can the most appropriate image / figure given the term:

Longitudinal
Axis

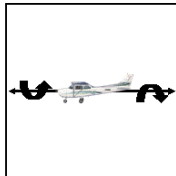
A



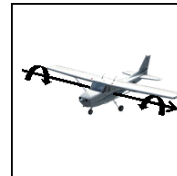
C



B



D



Slide 32

INSTRUCTIONS

Select as fast as you can the most appropriate image / figure given the term:

Lateral
Axis

A



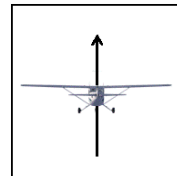
C



B



D



Slide 33

INSTRUCTIONS

Select as fast as you can the most appropriate image / figure given the term:

Lateral
Axis

A



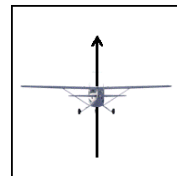
C



B



D



Slide 34

INSTRUCTIONS

Select as fast as you can the most appropriate image / figure given the term:

Gyroscopic
Instruments

A



C



B



D



Slide 35

INSTRUCTIONS

Select as fast as you can the most appropriate image / figure given the term:

Attitude Indicator

A



C



B



D



Slide 36

INSTRUCTIONS

Select as fast as you can the most appropriate image / figure given the term:

Turn Coordinator

A



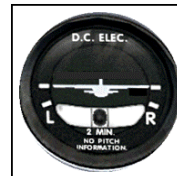
C



B



D



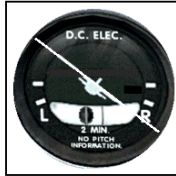
Slide 37

INSTRUCTIONS

Select as fast as you can the most appropriate image / figure given the term:

Standard rate
Turn

A



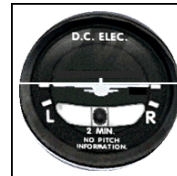
C



B



D



Slide 38

INSTRUCTIONS

Select as fast as you can the most appropriate image / figure given the term:

Heading
Indicator

A



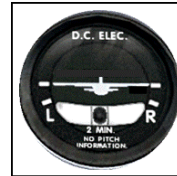
C



B



D



Slide 39

INSTRUCTIONS

Select as fast as you can the most appropriate image / figure given the term:

Pitot-static
Instruments

A



C



B



D



Slide 40

INSTRUCTIONS

Select as fast as you can the most appropriate image / figure given the term:

Airspeed
Indicator

A



C



B



D



Slide 41

INSTRUCTIONS

Select as fast as you can the most appropriate image / figure given the term:

Altimeter

A



C



B



D



Slide 42

INSTRUCTIONS

Select as fast as you can the most appropriate image / figure given the term:

Vertical Speed Indicator

A



C



B



D



Slide 43

INSTRUCTIONS

Select as fast as you can the most appropriate term given the image / figure:



A

Altimeter

C

Airspeed Indicator

B

Vertical Speed Indicator

D

Heading Indicator

Slide 44

INSTRUCTIONS

Select as fast as you can the most appropriate term given the image / figure:



A

Turn Coordinator

C

Attitude Indicator

B

Vertical Speed Indicator

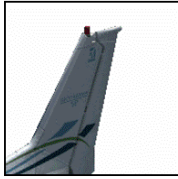
D

Heading Indicator

Slide 45

INSTRUCTIONS

Select as fast as you can the most appropriate term given the image / figure:



A

Elevators

C

Vertical Stabilizer

B

Rudder

D

Ailerons

Slide 46

INSTRUCTIONS

Select as fast as you can the most appropriate term given the image / figure:



A

Pitch

C

Vertical Axis

B

Yaw

D

Bank

INSTRUCTIONS

Select as fast as you can the most appropriate term given the image / figure:



A

Lateral
Axis

C

Vertical
Axis

B

Longitudinal
axis

D

Bank

APPENDIX J:
RC3 CAR TEST

TEST COMPLETE!

You will now be asked to complete a short test (12 items) with the same rules as the one you have just completed. The only difference is that the items are from the automotive industry.

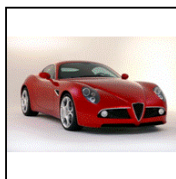
When you are ready click on continue and the short test will begin

INSTRUCTIONS

Select as fast as you can the most appropriate image / figure given the term:

Alfa Romeo
8C

A



C



B



D



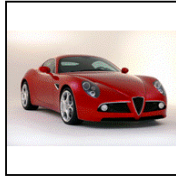
Slide 3

INSTRUCTIONS

Select as fast as you can the most appropriate image / figure given the term:

Dodge Viper

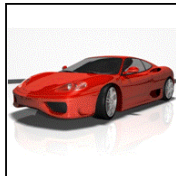
A



C



B



D



Slide 4

INSTRUCTIONS

Select as fast as you can the most appropriate image / figure given the term:



A

Saleen S7

C

Ford GT

B

Ferrari
Modena

D

Dodge Viper

Slide 5

INSTRUCTIONS

Select as fast as you can the most appropriate image / figure given the term:

Honda Fit

A



C



B



D



Slide 6

INSTRUCTIONS

Select as fast as you can the most appropriate image / figure given the term:

FIAT 500

A



C



B



D



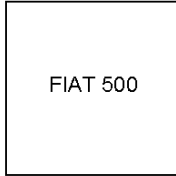
Slide 7

INSTRUCTIONS

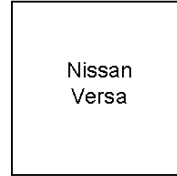
Select as fast as you can the most appropriate image / figure given the term:



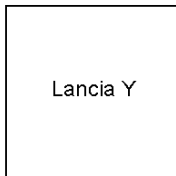
A



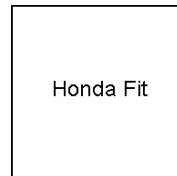
C



B



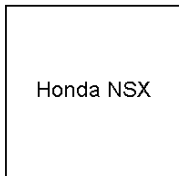
D



Slide 8

INSTRUCTIONS

Select as fast as you can the most appropriate image / figure given the term:



A



C



B



D



Slide 9

INSTRUCTIONS

Select as fast as you can the most appropriate image / figure given the term:

Ford GT

A



C



B



D



Slide 10

INSTRUCTIONS

Select as fast as you can the most appropriate image / figure given the term:



A

Audi R8

C

Porsche Carrera

B

Honda
NSX

D

Ford GT

Slide 11

INSTRUCTIONS

Select as fast as you can the most appropriate image / figure given the term:

VW GTI

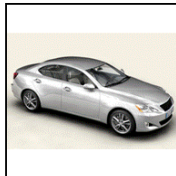
A



C



B



D



Slide 12

INSTRUCTIONS

Select as fast as you can the most appropriate image / figure given the term:

Audi A3

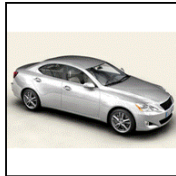
A



C



B



D



INSTRUCTIONS

Select as fast as you can the most appropriate image / figure given the term:



A

Audi A3

C

Golf GTI

B

Lexus IS

D

Scion tC

APPENDIX K:
DECLARATIVE TEST


Question 1 of 30	Where are the ailerons located?	A)top of the airplane, by the cockpit {0} B)midpoint of each wing toward the tip {1} C)top of the airplane, aft of the fuselage {0} D)midpoint of the fuselage towards the center {0}
Question 2 of 30	How do ailerons move?	A)in opposite directions {1} B)in the same direction {0} C)both move only up {0} D)both move only down {0}
Question 3 of 30	Why do pilots use the ailerons?	A)in order to yaw {0} B)in order to pitch {0} C)in order to coordinate a climb {0} D)in order to bank {1}
Question 4 of 30	Where are the elevators located?	A)back of the horizontal stabilizer {1} B)back of the vertical stabilizer {0} C)midpoint of each wing out to the tip {0} D)midpoint of the fuselage, centered on the cockpit {0}
Question 5 of 30	How do elevators move?	A)in opposite directions {0} B)in the same direction {1} C)both move only up {0} D)both move only down {0}
Question 6 of 30	Why do pilots use the elevators?	A)in order to yaw {0} B)in order to pitch {1} C)in order to coordinate a climb {0} D)in order to bank {0}
Question 7 of 30	What is the rudder attached to?	A)back of the horizontal stabilizer {0} B)back of the vertical stabilizer {1} C)midpoint of each wing out to the tip {0} D)midpoint of the fuselage, centered on the cockpit {0}
Question 8 of 30	Why do pilots use the rudder?	A)in order to yaw {1} B)in order to pitch {0} C)in order to coordinate a climb {0} D)in order to bank {0}
Question 9 of 30	What is the rudder used with in order to initiate a turn?	A)nothing else {0} B)the elevators {0} C)the ailerons {1} D)the propeller {0}
Question 10 of 30	Where is the vertical stabilizer located?	A)top of the airplane's tail {1} B)top of the airplane's nose {0} C)below the airplane's tail {0} D) below the airplane's nose {0}


Question 11 of 30	The center of gravity meets where the _____ intersect.	A)airplane surface moving parts {0} B)hydraulic lines {0} C)centrifugal forces {0} D)three axes of flight {1}
Question 12 of 30	The lateral axis runs _____ through the center of gravity.	A)parallel to the wings {1} B)parallel to the vertical stabilizer {0} C)from the nose to the tail of the airplane {0} D)perpendicular to the wings {0}
Question 13 of 30	The longitudinal axis runs _____ through the center of gravity.	A)parallel to the wings {0} B)parallel to the vertical stabilizer {0} C)from the nose to the tail of the airplane {1} D)perpendicular to the wings {0}
Question 14 of 30	The vertical axis runs _____ through the center of gravity.	A)parallel to the wings {0} B)parallel to the vertical stabilizer {0} C)from the nose to the tail of the airplane {0} D)perpendicular to the wings {1}
Question 15 of 30	The aircraft's attitude is relative to what?	A)the miniature airplane {0} B)the horizon {1} C)the heading {0} D)the altitude {0}
Question 16 of 30	The attitude indicator is used as _____.	A)an artificial horizon {1} B)a real horizon {0} C)a way to tell whether the plane is going up or down {0} D)as a way to determine the mood of the pilot {0}
Question 17 of 30	A _____ is a device for measuring or maintaining orientation.	A)pitot {0} B)gravitational converter {0} C)flux capacitor {0} D)gyroscope {1}
Question 18 of 30	When the plane turns, the heading card in the heading indicator _____.	A)rotates {1} B)is fixed {0} C)multiplies {0} D)there is no heading card in the heading indicator {0}
Question 19 of 30	What is the heading indicator sometimes called?	A)the lifeline {0} B)the rose of winds {0} C)the compass card {1} D)the pathfinder {0}
Question 20 of 30	What is a standard-rate turn?	A)the completion of a 2-degree turn in 360 minutes {0} B)a turn approved by the FAA to avoid fuselage stress {0} C)the completion of a 360-degree turn in 2 minutes {1} D)a turn that maximizes speed/altitude ratio {0}

Question 21 of 30	What is the turn coordinator used for?	A)to gauge an aircraft's rate of turn {1} B)to coordinate the turn radius with aircraft's speed {0} C)to coordinate the pilot's seat angle according to how steep a turn is {0} D)to gauge the speed difference from onset to outset of turn {0}
Question 22 of 30	What is yaw movement known as?	A)up and down nose movement {0} B)roll of the airplane {0} C)bank of the airplane {0} D)left and right nose movement {1}
Question 23 of 30	What color is the airspeed indicator arc for "never-exceed" speed?	A)black {0} B)red {1} C)orange {0} D)purple {0}
Question 24 of 30	The airspeed indicator is calibrated in _____.	A)miles per hour {0} B)knots {1} C)kilometers per hour {0} D)clicks {0}
Question 25 of 30	What information does the altimeter display?	A)changes in vertical movement of the airplane {1} B)the airplane's distance in feet from the ground {0} C)changes in longitudinal movement of the airplane {0} D)the airplane's distance in meters from the ground {0}
Question 26 of 30	What color is the airspeed indicator arc for caution speed?	A)orange {0} B)amber {0} C)scarlet {0} D)yellow {1}
Question 27 of 30	What color is the airspeed indicator arc for flaps operation?	A)white {1} B)black {0} C)grey {0} D)magenta {0}
Question 28 of 30	The flared triangular pointer in the altimeter shows _____.	A)100 feet intervals {0} B)500 feet intervals {0} C)1,000 feet intervals {1} D)5,000 feet intervals {0}
Question 29 of 30	The needle pointer in the altimeter shows _____.	A)100 feet intervals {1} B)500 feet intervals {0} C)1,000 feet intervals {0} D)5,000 feet intervals {0}

Question 30 of 30	What information does the vertical speed indicator display?	A)the speed of vertical lift {0} B)changes in the vertical rate of movement {1} C)the speed and magnitude of vertical force {0} D)changes in the vertical acceleration {0}
BoNuS QuEsTiOn!	What do you think about this experiment so far?	A)gee, can you guys make this more boring?? {1} B)woot! I love all this stuff about planes! {5} C)what kind of question is this?! I'm in it for the extra credit, duh! {2} D)I'm thinking that I'd rather be at home, but it's ok {3} E)I'm not like, super excited, but it's kinda interesting {4}

APPENDIX L:
INTEGRATIVE TEST

Question 1 of 25	In the video you just saw: Which answer best describes the airplane maneuver displayed by the instruments?	A)A climb from about 4,900 to 5,100 feet {1} B)A descent from about 4,900 to 5,100 feet {0} C)A climb from about 490 to 510 feet {0} D)A descent from about 490 to 510 feet {0} E)None of the above {0}
		


<p>Question 2 of 25</p>	<p>In the video you just saw: Which answer best describes the airplane maneuver displayed by the instruments?</p>	<p>A) A turn toward the South {0} B) A standard-turn toward the North {1} C) A steep turn toward the North {0} D) A nominal-turn toward to North {0} E) A nominal-turn to the South {0}</p>
 <p>The image shows two circular instruments from an aircraft's instrument panel. On the left is a Turn Coordinator, labeled 'D.C. ELEC.' and 'TURN COORDINATOR'. It features a scale with 'L' (left) and 'R' (right) markings and a needle pointing towards the left. Below the needle, it says '2 MIN. NO PITCH INFORMATION'. On the right is a Vacuum Gauge, labeled 'VACUUM'. It has a scale from 0 to 30 in increments of 3, with 'N' at the top and 'S' at the bottom. The needle is pointing to approximately 30. Below the gauge, there are two buttons labeled 'PUSH' and 'HOLD'.</p>		


Question 3 of 25	In the video you just saw: Which answer best describes the airplane maneuver displayed by the instruments?	A)An ascending right turn {0} B)An ascending left turn {0} C)A descending right turn {0} D)A descending left turn {1} E)None of the above {0}
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Question 4 of 25	In the video you just saw: Which answer best describes the airplane maneuver displayed by the instruments?	<p>A) A 6000 feet per minute ascent to 3,500 feet altitude {0}</p> <p>B) A 600 feet per minute ascent to 350 feet altitude {0}</p> <p>C) A 600 feet per minute ascent to 3,500 feet altitude {1}</p> <p>D) A 6000 feet per minute ascent to 350 feet altitude {0}</p> <p>E) A 600 mile per minute ascent to 35,000 feet altitude {0}</p>
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Question 5 of 25	In the video you just saw: Which answer best describes the airplane maneuver displayed by the instruments?	A)Steady-state acceleration {0} B)Accelerating climb {0} C)Decelerating descent {0} D)Accelerating descent {0} E)Decelerating climb {1}
		

<p>Question 6 of 25</p>	<p>In the video you just saw: Which answer best describes the airplane maneuver displayed by the instruments?</p>	<p>A)Accelerating left descending turn {0} B)Decelerating right climbing turn {1} C)Accelerating right climbing turn {0} D)Decelerating left climbing turn {0} E)Accelerating right descending turn {0}</p>
	 <p>The image shows three cockpit instruments. From left to right: 1. Airspeed Indicator (ASI) with a scale from 0 to 200 knots, showing a reading of approximately 180 knots. 2. Attitude Indicator (AI) showing a steep climb and a right turn. 3. Altimeter showing a reading of 29.9, indicating a descent.</p>	

<p>Question 7 of 25</p>	<p>In the video you just saw: Which answer best describes the airplane maneuver displayed by the instruments?</p>	<p>A)Accelerating left descending turn {1} B)Decelerating left descending turn {0} C)Accelerating right descending turn {0} D)Decelerating right descending turn {0} E)Accelerating left ascending turn {0}</p>
	 <p>The image shows three cockpit instruments. From left to right: an Airspeed Indicator (ASI) with a needle pointing to approximately 120 knots; an Attitude Indicator (AI) showing a steep climb and a left turn; and an Altimeter showing an altitude of approximately 29,900 feet.</p>	

Question 8 of 25	In the video you just saw: Which answer best describes the airplane maneuver displayed by the instruments?	A)Right descending turn towards the West {0} B)Left descending turn toward the North {0} C)Right descending turn toward the North {0} D)Left climbing turn toward the West {1} E)Right climbing turn toward the West {0}
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<p>Question 9 of 25</p>	<p>In the video you just saw: Which answer best describes the airplane maneuver displayed by the instruments?</p>	<p>A)Right ascending turn toward the North {0} B)Left descending turn toward the North {0} C)Right descending turn toward the North {1} D)Left ascending turn toward the North {0} E)two-minute turn towards the North {0}</p>
 <p>The image shows three cockpit instruments. From left to right: a turn coordinator with a scale from L to R and a needle pointing to the right; a heading indicator with a scale from 30 to 33 and a needle pointing to 33; and a vertical speed indicator with a scale from 0 to 20 and a needle pointing to approximately 10. The heading indicator also has a 'VACUUM' label and a 'PUSH' button. The vertical speed indicator has a '100 FEET PER MIN' label and a 'HDS' button.</p>		

Question 10 of 25	In the video you just saw: Which answer best describes the airplane maneuver displayed by the instruments?	A) Right ascending turn toward the North {0} B) Left descending turn toward the West {1} C) Right descending turn toward the North {0} D) Left descending turn toward the North {0} E) Right descending turn to the North {0}
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Question 11 of 25	In the video you just saw: Which answer best describes the airplane maneuver displayed by the instruments?	A) Descending and decelerating standard-turn to the right {1} B) Descending and decelerating standard-turn to the left {0} C) Descending and accelerating standard-turn to the right {0} D) Ascending and decelerating standard-turn to the right {0} E) Ascending and decelerating standard-turn to the left {0}
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Question 12 of 25	In the video you just saw: Which answer best describes the airplane maneuver displayed by the instruments?	A)Climbing and decelerating turn toward the North {0} B)Descending and decelerating turn toward the West {0} C)Climbing and accelerating turn toward the West {0} D)Descending and decelerating turn toward the North {0} E)Climbing and decelerating turn toward the West {1}
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<p>Question 13 of 25</p>	<p>In the video you just saw: Which answer best describes the airplane maneuver displayed by the instruments?</p>	<p>A)Right ascending turn toward the West {0} B)Right descending turn toward the West {1} C)Left descending turn toward the West {0} D)Left descending turn toward the North {0} E)None of the above {0}</p>
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Question 14 of 25	In the video you just saw: Which answer best describes the airplane maneuver displayed by the instruments?	A)Right ascending turn toward the East {1} B)Right descending turn toward the West {0} C)Left descending turn toward the East {0} D)Left descending turn toward the West {0} E)None of the above {0}
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Question 15 of 25	In the video you just saw: Which answer best describes the airplane maneuver displayed by the instruments?	A)Right ascending turn toward the North {0} B)Right descending turn toward the West {0} C)Left descending turn toward the North {1} D)Left descending turn toward the West {0} E)None of the above {0}
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Question
16 of 25

The pilot used the _____ to control the _____ movement. A primary instrument that would change as a result of this maneuver is the _____.

- A) elevators; yaw; airspeed indicator {0}
- B) rudder; yaw; altimeter {0}
- C) elevators; pitch; altimeter {1}
- D) rudder; pitch; airspeed indicator {0}
- E) elevators; pitch; turn-coordinator {0}



Question 17 of 25	During landing, the rate of descent should be monitored using the _____. Small adjustments around the _____ axis are performed using the _____ to keep the plane aligned to the runway.	A)attitude indicator; longitudinal; rudder {0} B)vertical speed indicator; longitudinal; ailerons {1} C)altimeter; vertical; rudder {0} D)vertical speed indicator; lateral; rudder {0} E)attitude indicator; vertical; ailerons {0}
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Question
18 of 25

The airplane in the video performed several _____ movements using the _____. Such maneuver would be best indicated on the _____.

- A)pitch; ailerons; attitude indicator {1}
- B)yaw; rudder; turn coordinator {0}
- C)pitch; rudder; altimeter {0}
- D)yaw; ailerons; heading indicator {0}
- E)pitch; elevators; vertical speed indicator {0}



Question 19 of 25	The airplane in the video performed a _____ turn using both _____ and _____. Such maneuver would be best followed on the _____.	A)coordinated; elevators; rudder; attitude indicator {0} B)steady-state; ailerons; elevators; altimeter {0} C)coordinated; elevators; ailerons; heading indicator {0} D)steady-state; rudder; elevators; airspeed indicator {0} E)coordinated; ailerons; rudder; turn coordinator {1}
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Question 20 of 25	While initially _____ the pilot also subsequently _____ the plane. Overall, _____ moving surface part(s) was(were) used	A)banking; pitched; all {1} B)yawed; pitched; two {0} C)banking; yawed; two {0} D)yawing; banked; all {0} E)pitching; yawed; two {0}
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Question 21 of 25	The pilot used the _____ to _____ the airplane. Such maneuver is best reflected in the _____.	A)ailerons; pitch; vertical speed indicator {0} B)rudder; pitch; attitude indicator {0} C)elevators; bank; airspeed indicator {0} D)rudder; yaw; heading indicator {1} E)ailerons; bank; attitude indicator {0}
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Question
22 of 25

The pilot is _____ the plane. As a
result, the plane _____ and _____.

- A)pitching; climbs; decelerate {0}
- B)banking; climbs; accelerates {0}
- C)pitching; decelerates; descends {1}
- D)banking; descends; decelerate {0}
- E)pitching; accelerates; descends {0}



Question 23 of 25	The pilot performed a steep movement around the _____ axis using the _____. Only _____ instrument(s) is(are) unaffected by this maneuver.	A)vertical; ailerons; one {0} B)lateral; ailerons; three {0} C)vertical, elevators; two {0} D)lateral; elevators; two {1} E)vertical; rudder; four {0}
----------------------	---	--



Question 24 of 25	During takeoff the pilot must monitor acceleration on the _____ to tell when to begin to _____ using the _____.	A)airspeed indicator; pitch; elevators {1} B)vertical speed indicator; pitch; elevators {0} C)airspeed indicator; yaw; rudder {0} D)vertical speed indicator; yaw,; rudder {0} E)airspeed indicator; bank; ailerons {0}
----------------------	---	---



Question
25 of 25

The pilot used the _____ to
_____ the plane around the
_____ axis.

- A) elevators; pitch; lateral {1}
- B) rudder; yaw; vertical {0}
- C) ailerons; bank; longitudinal {0}
- D) flaps; drag; longitudinal {0}
- E) nose; point; vertical {0}



APPENDIX M:
SPATIAL ABILITY TEST

Slide 1

INSTRUCTIONS

This is a test of how well you are able to visualize spatial positions. In each item you are to note how the clock would move if it were moved as indicated by the arrow on the sphere.

Here are some sample items.

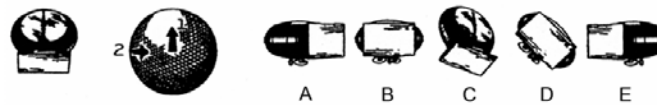


The first picture at the left shows a clock. Next to it is a sphere with an arrow marked on it. The arrow shows how the clock is to be moved. This move is illustrated (in two steps) in the picture below. When the clock is moved to the one-quarter turn shown by the arrow, it is then in position B. B is therefore the correct answer.



Continue ▶

Slide 2



Two movements of the clock are called for by the two arrows on the sphere. Move number 1 must be visualized first. Move number 2 must be started from the clock's position after the first move. In this item, each arrow shows one-eighths of a turn. The two moves, if visualized correctly, would place the clock in position A. The picture below illustrate, in two steps, how the moves would be visualized, one following the other.



In some of the items, three moves will be called for. Remember that each move, after the first, must be started from the clock's position after the previous move has been completed. Next, you will be asked to try three sample items, before the actual test begins.

◀ Go Back

Continue ▶

Slide 3

Sample item 1

If you select the wrong answer you will be prompted to try again. You will be moving to the next item only when the right answer has been chosen.



A B C D E

◀ Go Back

Slide 4

Sample item 2

Good! Now try the second sample item. You will be moving to the next item only when the right answer has been chosen.



A B C D E

◀ Go Back

Slide 5

Sample item 3

Excellent! Now try the last sample item. You will be moving to the next item only when the right answer has been chosen.



A B C D E

[← Go Back](#)

Slide 6

Sample item 3

Excellent! Now try the last sample item. You will be moving to the next item only when the right answer has been chosen.



A B C D E

[← Go Back](#)

Slide 7

Item 1



Click your selected response:

- A B C D E

Slide 8

Item 2



Click your selected response:

- A B C D E

[◀ Go Back](#)

Slide 9

Item 3



Click your selected response:

- A
- B
- C
- D
- E

◀ Go Back

Slide 10

Item 3



Click your selected response:

- A
- B
- C
- D
- E

◀ Go Back

Slide 11

Item 5



Click your selected response:

- A B C D E

◀ Go Back

Slide 12

Item 6



Click your selected response:

- A B C D E

◀ Go Back

Slide 13

Item 7



Click your selected response:

- A
- B
- C
- D
- E

◀ Go Back

Slide 14

Item 8



Click your selected response:

- A
- B
- C
- D
- E

◀ Go Back

Slide 15

Item 9



Click your selected response:

- A B C D E

◀ Go Back

Slide 16

Item 10



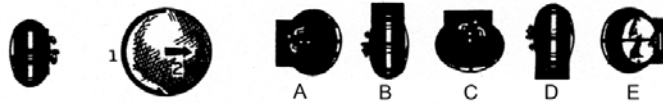
Click your selected response:

- A B C D E

◀ Go Back

Slide 17

Item 11



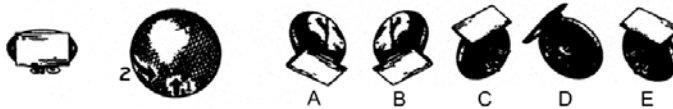
Click your selected response:

- A B C D E

◀ Go Back

Slide 18

Item 12



Click your selected response:

- A B C D E

◀ Go Back

Slide 19

Item 13



Click your selected response:

- A
- B
- C
- D
- E

◀ Go Back

Slide 20

Item 14



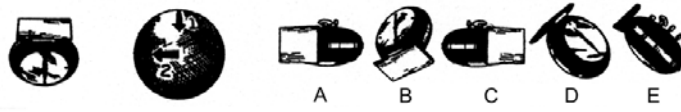
Click your selected response:

- A
- B
- C
- D
- E

◀ Go Back

Slide 21

Item 15



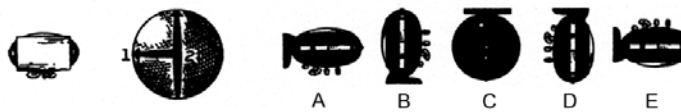
Click your selected response:

- A
- B
- C
- D
- E

◀ Go Back

Slide 22

Item 16



Click your selected response:

- A
- B
- C
- D
- E

◀ Go Back

Slide 23

Item 17



Click your selected response:

- A B C D E

◀ Go Back

Slide 24

Item 18



Click your selected response:

- A B C D E

◀ Go Back

Slide 25

Item 19



Click your selected response:

- A B C D E

◀ Go Back

Slide 26

Item 20



Click your selected response:

- A B C D E

◀ Go Back

Slide 27

Item 21



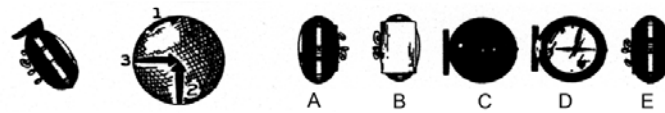
Click your selected response:

- A
- B
- C
- D
- E

◀ Go Back

Slide 28

Item 22



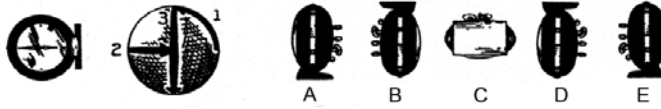
Click your selected response:

- A
- B
- C
- D
- E

◀ Go Back

Slide 29

Item 23



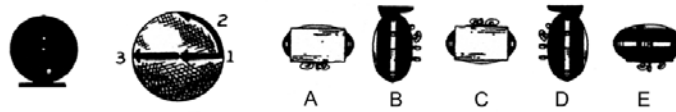
Click your selected response:

- A
- B
- C
- D
- E

◀ Go Back

Slide 30

Item 24



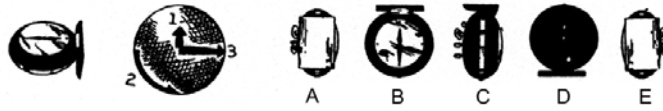
Click your selected response:

- A
- B
- C
- D
- E

◀ Go Back

Slide 31

Item 25



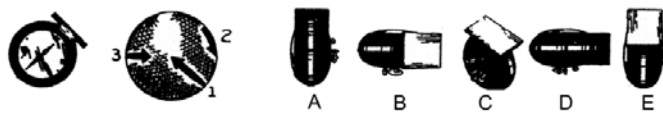
Click your selected response:

- A B C D E

◀ Go Back

Slide 32

Item 26



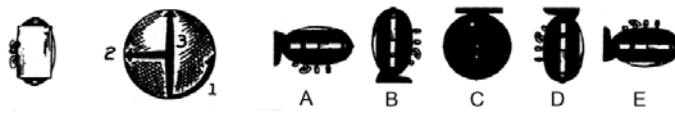
Click your selected response:

- A B C D E

◀ Go Back

Slide 33

Item 27



Click your selected response:

- A B C D E

◀ Go Back

Slide 34

Item 28



Click your selected response:

- A B C D E

◀ Go Back

Slide 35

Item 29



Click your selected response:

- A
- B
- C
- D
- E

◀ Go Back

Slide 36

Item 30



Click your selected response:

- A
- B
- C
- D
- E

◀ Go Back

Slide 37

Item 31



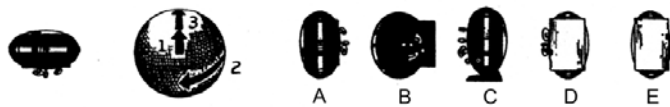
Click your selected response:

- A B C D E

◀ Go Back

Slide 38

Item 32



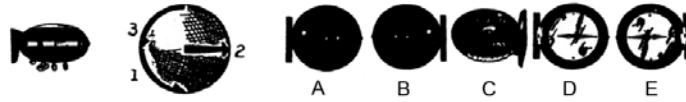
Click your selected response:

- A B C D E

◀ Go Back

Slide 39

Item 33



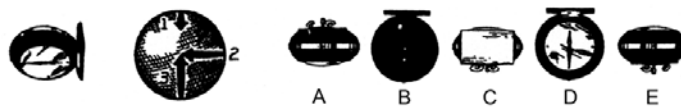
Click your selected response:

- A
- B
- C
- D
- E

◀ Go Back

Slide 40

Item 34



Click your selected response:

- A
- B
- C
- D
- E

◀ Go Back

Slide 41

Item 35



Click your selected response:

- A B C D E

◀ Go Back

Slide 42

Item 36



Click your selected response:

- A B C D E

◀ Go Back

Slide 43

Item 37



Click your selected response:

- A B C D E

◀ Go Back

Slide 44

Item 38



Click your selected response:

- A B C D E

◀ Go Back

Slide 45

Item 39



Click your selected response:

- A B C D E

◀ Go Back

Slide 46

Item 40



Click your selected response:

- A B C D E

◀ Go Back

Slide 47

This was your last item. If you wish, you can review your answers at this time.

CLICK CONTINUE TO END THIS TEST

◀ Go Back

Continue ▶

APPENDIX N:
VERBAL ABILITY TEST

Slide 1

INSTRUCTIONS

This is a test of how well you understand words. In each item, look first at the word in large letters and think what it means. Following it in smaller type, are five other words. Select the one of these that has a meaning like that of the word in large type.

Notice the following example.

TO REAP

- A. to flatter
- B. to harvest
- C. to refer
- D. to release
- E. to repose

The word that means the same as "REAP" is "harvest," which is answer B.

Click on 'continue' on the lower right portion of the screen to try two sample items

[➤ Continue](#)

Slide 2

INSTRUCTIONS

Sample item 1

Click the letter that goes with the word you have selected. If you do not know the answer, click on skip. If you skip an item it will be counted as missed (but not wrong). Since this is a sample item, you will only move to the next sample item when the correct answer is chosen.

EARTH

- A. sugar
- B. farm
- C. sun
- D. soil
- E. horse

Slide 3

INSTRUCTIONS

Sample item 2

Click the letter that goes with the word you have selected. If you do not know the answer, click on skip. If you skip an item it will be counted as missed (but not wrong). Since this is a sample item, you will only move to the next sample item when the correct answer is chosen.

SICK

- A. warm
- B. green
- C. ill
- D. soil
- E. horse

A B C D E skip

Slide 4

If you have any questions call your experimenter now

- You will have 10 minutes to complete this exercise
- If you do not know the answer to an item you may guess, but avoid wild guessing
- If you do not want to guess and do not know the answer, click on skip
- Your total score will be the number of right answers minus a small fraction of the number of wrong answers.

CLICK ON CONTINUE TO BEGIN THE TEST

➤ Continue

Slide 5

MERRY

- A. trim
- B. vast
- C. gay
- D. worthy
- E. damp

A B C D E skip

Slide 6

TO HEAP

- A. to pile
- B. to forbid
- C. to proceed
- D. to share
- E. to stoop

A B C D E skip

Slide 7

CARGO

- A. cabbage
- B. camel
- C. lance
- D. freight
- E. flax

A B C D E skip

Slide 8

MISERY

- A. mischief
- B. mystery
- C. rage
- D. destruction
- E. distress

A B C D E skip

VOLUME

- A. vice
- B. quantity
- C. vigor
- D. violence
- E. variety

A B C D E skip

TO HAMPER

- A. to evaporate
- B. to obstruct
- C. to forage
- D. to heighten
- E. to query

A B C D E skip

Slide 11

TO MERIT

- A. to embrace
- B. to devote
- C. to deserve
- D. to combine
- E. to display

A B C D E skip

Slide 12

BRIM

- A. border
- B. fluid
- C. brace
- D. bread
- E. braid

A B C D E skip

Slide 13

TRANQUIL

- A. transparent
- B. beset
- C. precise
- D. serene
- E. servile

A B C D E skip

Slide 14

TO RENOUNCE

- A. to rend
- B. to reject
- C. to ransom
- D. to soothe
- E. to beguile

A B C D E skip

Slide 15

TO BAFFLE

- A. to gamish
- B. to blanch
- C. to rant
- D. to repel
- E. to frustrate

A B C D E skip

Slide 16

MEAGER

- A. ardent
- B. blithe
- C. scant
- D. massive
- E. copious

A B C D E skip

OBSTINATE

- A. melancholy
- B. sullen
- C. stubborn
- D. reverent
- E. obscure

A B C D E skip

TO INSTIGATE

- A. to secede
- B. to retard
- C. to debar
- D. to incite
- E. to radiate

A B C D E skip

TO EMANCIPATE

- A. to liberate
- B. to extenuate
- C. to placate
- D. to expostulate
- E. to exhilarate

A B C D E skip

TO HOVER

- A. to linger
- B. to entice
- C. to hug
- D. to babble
- E. to gird

A B C D E skip

Slide 21

BELIEF

- A. vow
- B. zeal
- C. honor
- D. conviction
- E. mirth

A B C D E skip

Slide 22

TO STIFLE

- A. to embark
- B. to purify
- C. to bide
- D. to grope
- E. to smother

A B C D E skip

DISCRETION

- A. prudence
- B. consistency
- C. precipice
- D. disturbance
- E. distemper

A B C D E skip

TO ALIENATE

- A. to assuage
- B. to estrange
- C. to retrieve
- D. to quaver
- E. to transcend

A B C D E skip

TO SOLICIT

- A. to purge
- B. to spurn
- C. to entrance
- D. to exert
- E. to beseech

A B C D E skip

POTENTIAL

- A. latent
- B. hysterical
- C. conventional
- D. symmetrical
- E. conscientious

A B C D E skip

TO VEER

- A. to elicit
- B. to flounce
- C. to dislodge
- D. to culminate
- E. to diverge

A B C D E skip

TO SUBSIDE

- A. to negotiate
- B. to reiterate
- C. to blunder
- D. to wane
- E. to surmise

A B C D E skip

TO CONFISCATE

- A. to harass
- B. to repulse
- C. to console
- D. to appropriate
- E. to congregate

A B C D E skip

CAPRICE

- A. chattel
- B. impetus
- C. whim
- D. adage
- E. capability

A B C D E skip

ADHESIVE

- A. miry
- B. lucrative
- C. emetic
- D. lustrous
- E. tenacious

A B C D E skip

LATITUDE

- A. scope
- B. segment
- C. globule
- D. legislature
- E. lamentation

A B C D E skip

INERT

- A. antique
- B. passive
- C. abstract
- D. fragile
- E. sordid

A B C D E skip

TO COVET

- A. to crave
- B. to claim
- C. to avenge
- D. to clutch
- E. to comply

A B C D E skip

TO EFFACE

- A. to gnash
- B. to obliterate
- C. to exasperate
- D. to immerse
- E. to compile

A B C D E skip

TO CONCUR

- A. to acquiesce
- B. to extricate
- C. to divulge
- D. to concoct
- E. to ransack

A B C D E skip

FURTIVE

- A. ecstatic
- B. heinous
- C. stealthy
- D. flimsy
- E. facile

A B C D E skip

INCENTIVE

- A. reflex
- B. amplitude
- C. inflection
- D. provocation
- E. escutcheon

A B C D E skip

Slide 39

TOLERRANT

- A. tortuous
- B. rampant
- C. irrational
- D. indulgent
- E. sedentary

A B C D E skip

Slide 40

LETHARGY

- A. reminiscence
- B. category
- C. fallacy
- D. unanimity
- E. stupor

A B C D E skip

Slide 41

TO ADMONISH

- A. to conspire
- B. to usurp
- C. to allege
- D. to nibble
- E. to caution

A B C D E skip

Slide 42

MOMENTARY

- A. financial
- B. prevalent
- C. transient
- D. expedient
- E. incessant

A B C D E skip

PRETENTIOUS

- A. predatory
- B. ostentatious
- C. pernicious
- D. philanthropic
- E. oratorical

A B C D E skip

TO DISPEL

- A. to dissipate
- B. to dissent
- C. to distort
- D. to disfigure
- E. to dissect

A B C D E skip

Slide 45

INDOLENT

- A. contrite
- B. inexhaustible
- C. impervious
- D. arduous
- E. slothful

A B C D E skip

Slide 46

TO COALESCE

- A. to ratiocinate
- B. to amalgamate
- C. to surrogate
- D. to confute
- E. to expedite

A B C D E skip

ASTUTE

- A. bizarre
- B. ascetic
- C. sagacious
- D. lineal
- E. irritable

A B C D E skip

TO INFER

- A. to intervene
- B. to inject
- C. to defer
- D. to deduce
- E. to infest

A B C D E skip

LOQUACIOUS

- A. squalid
- B. solicitous
- C. invidious
- D. garrulous
- E. baneful

A B C D E skip

TO OSCILLATE

- A. to premeditate
- B. to irradiate
- C. to vacillate
- D. to recapitulate
- E. to furbish

A B C D E skip

Slide 51

TO RESCIND

- A. to abrogate
- B. to reconnoiter
- C. to cajole
- D. to reciprocate
- E. to vitiate

A B C D E skip

Slide 52

DISPARITY

- A. despondency
- B. mediocrity
- C. serenity
- D. incongruity
- E. assiduity

A B C D E skip

CORRELATIVE

- A. flagitious
- B. reciprocal
- C. sporadic
- D. connubial
- E. expeditious

A B C D E skip

DOLOROUS

- A. lugubrious
- B. indecorous
- C. rancorous
- D. herbaceous
- E. sacrilegious

A B C D E skip

Slide 55

LICENTIOUS

- A. fortuitous
- B. punctilious
- C. implicit
- D. fervid
- E. dissolute

A B C D E skip

Slide 56

DROLL

- A. insidious
- B. audacious
- C. snobbish
- D. ludicrous
- E. decrepit

A B C D E skip

INIQUITOUS

- A. congenital
- B. unassailable
- C. nefarious
- D. ubiquitous
- E. meretricious

A B C D E skip

TO EXPIATE

- A. to attune
- B. to accrue
- C. to exterminate
- D. to atone
- E. to narrate

A B C D E skip

Slide 59

INDIGENT

- A. refractory
- B. fiscal
- C. destitute
- D. tolerable
- E. diligent

A B C D E skip

Slide 60

EPHEMERAL

- A. autocratic
- B. evanescent
- C. emulous
- D. empyrean
- E. jocular

A B C D E skip

CURSORY

- A. complacent
- B. gracious
- C. abusive
- D. desultory
- E. aquiline

A B C D E skip

ANTIPATHY

- A. contradiction
- B. collusion
- C. abhorrence
- D. diffidence
- E. incredulity

A B C D E skip

Slide 63

ENNUI

- A. consanguinity
- B. cozenage
- C. ensilage
- D. lassitude
- E. hetacomb

A B C D E skip

Slide 64

TO CONFABULATE

- A. to inveigh
- B. to regress
- C. to ossify
- D. to discompose
- E. to palaver

A B C D E skip

PROBITY

- A. triviality
- B. versatility
- C. obesity
- D. veracity
- E. temerity

A B C D E skip

TAWDRY

- A. untidy
- B. garish
- C. obtrusive
- D. sparse
- E. lascivious

A B C D E skip

IRASCIBLE

- A. vapid
- B. insensate
- C. ecliptic
- D. heretical
- E. choleric

A B C D E skip

CUPIDITY

- A. gratuity
- B. avidity
- C. flaccidity
- D. frugality
- E. sagacity

A B C D E skip

SUCCINCT

- A. ribald
- B. omnivorous
- C. depraved
- D. hymeneal
- E. laconic

A B C D E skip

ENCOMIUM

- A. apocalypse
- B. cabal
- C. eulogy
- D. indolence
- E. epitome

A B C D E skip

Slide 71

TYRO

- A. neophyte
- B. turbulence
- C. publicist
- D. agrarian
- E. timbrel

A B C D E skip

Slide 72

PROLIXITY

- A. perspicuity
- B. derogation
- C. verbosity
- D. defalcation
- E. prebendary

A B C D E skip

TO VILIFY

- A. to digress
- B. to emprise
- C. to iterate
- D. to incarcerate
- E. to traduce

A B C D E skip

HIATUS

- A. caesura
- B. furbelow
- C. cygnet
- D. isobar
- E. davit

A B C D E skip

PERIPATETIC

- A. insensate
- B. itinerant
- C. unctuous
- D. palliative
- E. strident

A B C D E skip

ESOTERIC

- A. redolent
- B. effulgent
- C. recondite
- D. epistolary
- E. axiomatic

A B C D E skip

APPENDIX O:
COLOR VISION TEST

Slide 1

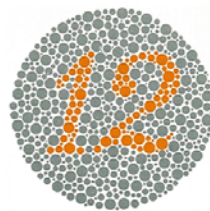
In the following task, you will be presented with 12 stimuli that assess your ability to perceive numbers embedded within patterns. For each stimulus you will be asked to write what number you see in the patterns of dots. If you do not see a number inside the pattern of dots, then write "00".

Continue ▶

Slide 2

Here is a sample item of the task you will perform. Please look at the picture below. What number do you see revealed in the pattern of dots below?

You should see the number "12" inside the pattern of dots. So, you would write "12" for this stimulus. If you have any questions, please ask now. Otherwise, proceed when you are ready to begin.

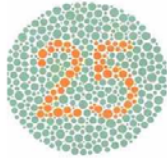


◀ Go Back

Continue ▶

Slide 3

Please write the number you see



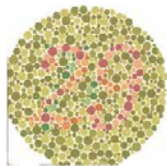
Press ENTER when you have typed your answer

◀ Go Back

Continue ▶

Slide 4

Please write the number you see



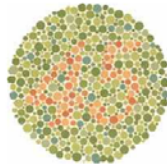
Press ENTER when you have typed your answer

◀ Go Back

Continue ▶

Slide 5

Please write the number you see



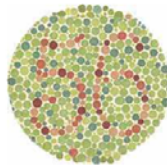
Press ENTER when you have typed your answer

◀ Go Back

Continue ▶

Slide 6

Please write the number you see



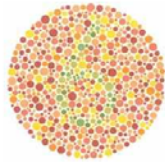
Press ENTER when you have typed your answer

◀ Go Back

Continue ▶

Slide 7

Please write the number you see



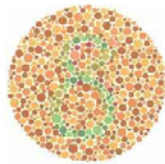
Press ENTER when you have typed your answer

◀ Go Back

Continue ▶

Slide 8

Please write the number you see



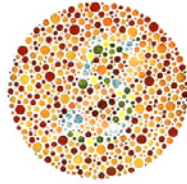
Press ENTER when you have typed your answer

◀ Go Back

Continue ▶

Slide 9

Please write the number you see



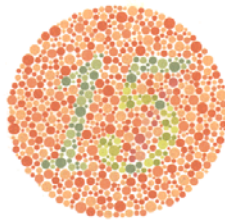
Press ENTER when you have typed your answer

◀ Go Back

Continue ▶

Slide 10

Please write the number you see



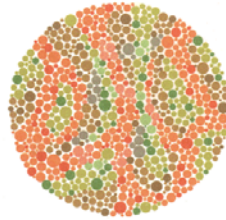
Press ENTER when you have typed your answer

◀ Go Back

Continue ▶

Slide 11

Please write the number you see



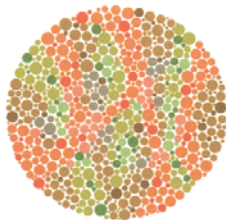
Press ENTER when you have typed your answer

◀ Go Back

Continue ▶

Slide 12

Please write the number you see



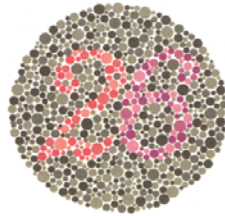
Press ENTER when you have typed your answer

◀ Go Back

Continue ▶

Slide 13

Please write the number you see



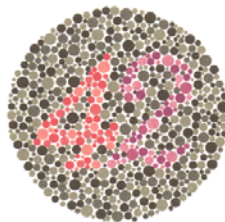
Press ENTER when you have typed your answer

◀ Go Back

Continue ▶

Slide 14

Please write the number you see



Press ENTER when you have typed your answer

◀ Go Back

Continue ▶

APPENDIX P:
INFORMED CONSENT

Student Informed Consent Form

Name: _____ **Identification No.:** _____

You agree to participate in the study “*Investigating the Relationship between Referential Connections and Learning in a Multimedia Computer-Based Training Environment: The Impact of Temporal Contiguity and Color-Coding on Knowledge Acquisition*,” conducted by principal investigator Sandro Scielzo.

You must be **18 years or older** to participate in this study. In this research, you will participate in a computer-based training program aimed at teaching you the principles of flight. We want to determine which type of training design yield better learning outcomes. A knowledge test along with aptitude measures (e.g., verbal and spatial aptitude) and a color vision test will be given to you during the experiment. Performance on these tasks will remain completely confidential (see below). The experiment should take approximately 90 minutes. Upon completion of the study, course credit for participation in an experiment will be given in accordance with the procedures established within the Department of Psychology.

Risks and Benefits

Participation in the current study does not involve any risks other than those commonly associated with the use of computer display terminals. Also, performance and personal data will be kept confidential.

If you should suffer physical injury during participation in this research project, the University will provide referrals to appropriate health care facilities. Any treatment you receive will be charged to your insurance carrier, to any other party responsible for your treatment costs, or to you.

You acknowledge that the University of Central Florida is an agency of the State of Florida and the University of Central Florida’s operations and liabilities are regulated by Florida law, including the University of Central Florida’s ability to indemnify any person, firm or corporation for injury or loss caused by the University of Central Florida; that the State of Florida is self-insured to the extent of its liability under law; and that liability in excess of that specified in statute may be awarded only through special legislative action. Accordingly, the University of Central Florida’ ability to compensate you for any injury suffered during this research study is very limited.

Research at the University of Central Florida is conducted under the oversight of the UCF Institutional Review Board. Questions or concerns about research participants’ rights may be directed to:

UCF IRB office
University of Central Florida
Office of Research & Commercialization
12201 Research Parkway, Suite 501
Orlando, FL 32826-3246
Tel: 407-823-2901

Confidentiality of Personal Data:

All data you will contribute to this study will be held in strict confidentiality by the researchers. That is, your individual data will not be revealed to anyone other than the researchers and their immediate assistants.

To insure confidentiality, the following steps will be taken: (a) only the principal investigator will have access to the data in paper or electronic form. Data will be stored in locked facilities and password protected on computers; (b) the actual forms will not contain names or other personal information. Instead, the forms will be matched to each participant by a number assigned by and only known to the principal investigator; (c) only group means scores and standard deviations, but not individual scores, will be published or reported.

YOUR PARTICIPATION IN THIS RESEARCH IS COMPLETELY VOLUNTARY. YOU CAN WITHDRAW YOUR PARTICIPATION AT ANY TIME WITHOUT PENALTY OR PERJURY - THIS INCLUDES REMOVAL/DELETION OF ANY DATA YOU MAY HAVE CONTRIBUTED. SHOULD YOU DECIDE NOT TO COMPLETE THE TRAINING STUDY, HOWEVER, YOU WILL BE ELIGIBLE ONLY TO THE COURSE CREDIT FOR THAT PART OF THE STUDY THAT YOU HAVE COMPLETED.

This research is conducted by principal investigator Sandro Scielzo. You have been given the opportunity to ask the experimenter any questions you may have. For any other questions regarding this research, you can contact Sandro Scielzo:



I have read the procedure described above. I voluntarily agree to participate in the procedure and I have received a copy of this description.

Signature: _____ Date: _____

APPENDIX Q:
EXPERIMENTER'S SCRIPT

PROCEDURES FOR MULTIMEDIA EXPERIMENT – SPRING 2008

Pre-Experiment Checklist:

- Arrive at least 10 minutes prior to the scheduled session
- Keep the lab door open
- On the experimenter's table:
 - o Make sure that we have enough informed consent forms and experiment evaluation forms (if we don't please contact Javier or Sandro right away)
 - o Make sure that we have at least two pens (one for the participant and one for you)
 - o Make sure that we have the lab log-sheet
 - o Make sure that we have enough extended log-sheets (the form used to write-up lengthy issues)
 - o Make sure that we have file folders. Take one folder and write the participants' number on its tab according to the lab log sheet
- On the laptop table
 - o Make sure there is a pen
 - o Place the laptop about 4-5 inches away and parallel from the edge of the desk
 - o Verify that the power cord is properly inserted, and turn on the computer
 - o When an error message appears on login, please click 'ok' or press 'enter'
 - o On the main login page select the MULTIMEDIA account
 - Password is 'TPL', all caps
- On the log sheet check the SS and condition number for your next participant
- Click on the "experiment" icon in the middle of the desktop screen
- Insert the correct participant number and condition (Please double check), **DO NOT PRESS OK** yet
- Informed consent form: write down (top-right) the participant's number and condition (e.g., 1-1, 23-6, etc.)
- If the participant arrives more than 15 minutes late, and we have participants scheduled in this lab back to back we will have to reschedule him/her (Call Javier)

When the participants arrives:

Read verbatim: "*Hi, my name is _____, and I will be your experimenter today. Please have a seat right here in front of the laptop*"

→ Indicate where to sit, take the informed consent form, and when the participant is sitting:

Read verbatim: "*Thank you. Please complete the following form*"

→ At this point, give participant the informed consent form. Close the lab door and attach the busy sign on the outside. Fill-in the information on the lab log-sheet (i.e., your name, time, and date). When the participant has signed the informed consent form:

Read verbatim: *“Thank you. Do you have any questions before we begin this experiment?”*

→ Answer eventual questions, unless they are related to the purpose of this experiment. Place the informed consent form in the participant’s folder on the experimenter’s desk. When done:

Read verbatim: *“We are now going to calibrate the angle of the screen in order to maximize the screen’s contrast-ratio”*

→ Make sure the participant sits right in the middle when looking at the laptop. Double check – again – that the right codes are entered in the window, and then click “Ok.” When the briefing loads up, used the dark back-arrow to show the participant how to calibrate the screen (i.e., adjusting the angle of the screen). Once the screen is calibrated:

Read verbatim: *“You are now ready to begin the experiment. Please follow all the instructions on the screen. If at any point in time you have questions or need to take a break, please let me know. I will be sitting at that table [indicate the experimenter’s table with a gesture] for the duration of this experiment in case you need help. You may now proceed.”*

During the Experiment:

- Keep the extended log sheet next to you, and write down anything out of the ordinary
 - o When you write down an event (e.g., noise), always make sure to log the time of the event and what the participant is doing at that time.
- You can do reading or writing, but no typing, drinking, eating, messaging, or anything else that may affect the neutrality of the environment

During the Five-Minute Break:

→ Let the participant know that s/he can go out of the lab at this point (e.g., restrooms, calls, etc.). Open the door if necessary. Close the door when participant comes back. Make sure when they sit back down that they are seated with the laptop right in front of them so that we do not lose screen calibration

When the Experiment is done:

→ Make sure that you have the experiment evaluation form handy

Read verbatim: *“Thank you for your participation. Here is an anonymous form that the psychology department would like you to complete in order to provide feedback on this experiment that you have just completed. Let me know if you have any questions.”*

→ After answering eventual questions:

Read verbatim: *“Have a good day”*

→ You can now crack a joke or interact informally with the participant if you really want to (but as usual remain as politically correct as possible!). Remember that your behavior reflect on the entire lab

When the participant leaves the lab:

- Remove the busy sign from the door
- Complete lab log-sheet:
 - o Write ‘OK’ is nothing out of the ordinary happened
 - o Write ‘See extended log-sheet’ if you have recorded unusual events
- Place the extended log-sheet (unless empty) in the participant’s folder along with the informed consent form
- Organize area for the next session

Post-Experiment Checklist:

- If this is the last session of the day:
 - o Power off the laptop
 - o Close the screen lid
- Report to Javier if we are running low on any forms or supplies

If the participant is malingering:

→ If you catch the participant not paying attention to the task at hand, please say diplomatically: *“I’m sorry to interrupt, but could you make sure to pay closer attention to the task? Thank you”*

→ If the participant repeatedly (more than twice) ignores your warnings, please say diplomatically: *“I’m afraid that if you cannot pay more attention to the study I will have to terminate this session and you will only get extra-credit for the time you have spent so far.”*

→ Call Sandro (407-701-6408) if the participant is uncooperative, or if there are any outstanding issues. Call 9-1-1 in case of emergency

Remember the three ‘Cs’ of ethical behavior: be courteous, concerned, and caring

APPENDIX R:
CBT BRIEFING

Slide 1



Principles of Flight Training – Experiment Briefing



- Thank you for participating in our experiment!
- If, at any time, you have questions or need to take a break, please feel free to ask
- The purpose of this briefing is to describe:
 - The purpose of this training
 - The different parts and measures associated with this training



Click on the arrow buttons on the top-right portion of the screen to go back and forth in this tutorial

Slide 2



Principles of Flight Training – Experiment Briefing



- This experiment is part of a doctoral dissertation sponsored by the Team Performance Laboratory (TPL) aimed at investigating the effects that varying multimedia content has on learning
- At the end of this experiment you will be fully debriefed, and any question you may have about this study will be answered
- Specifically, the purpose of this experiment is to:
 - Teach you the principles of flight using a computer-based training tutorial
 - Use multimedia design principles that may or may not facilitate your learning

Slide 3



Principles of Flight Training – Experiment Briefing



- Thanks to your valued participation, the information we collect may improve our understanding on how learning occurs when using multimedia content in two ways:

- Theoretical gains: your contribution can help us further refine cognitive models of learning
- Practical gains: your contribution can help us develop enhanced design guidelines for computer-based multimedia training

- Because of the importance of this study, we need you to stay focused and try your very best when proceeding through the experiment

Slide 4



Principles of Flight Training – Experiment Briefing



- This experiment is divided into four sessions
 - Session 1: Biographical data and Color Vision Test
 - Session 2: Training tutorial on the principles of flight
 - Session 3: Spatial aptitude and verbal aptitude measures
 - Session 4: Knowledge test

- Session 1 (about 10 minutes):
 - A short biographical questionnaire will collect background information
 - A color vision test will measure your color vision performance

Slide 5



Principles of Flight Training – Experiment Briefing



- This experiment is divided into four sessions
 - Session 1: Biographical data and Color Vision Test
 - Session 2: Training tutorial on the principles of flight
 - Session 3: Spatial aptitude and verbal aptitude measures
 - Session 4: Knowledge test

- Session 2 (about 20 minutes) :
 - A training tutorial on the principles of flight will teach you:
 - Airplane dynamics
 - Airplane main instruments

Slide 6



Principles of Flight Training – Experiment Briefing



- This experiment is divided into four sessions
 - Session 1: Biographical data and Color Vision Test
 - Session 2: Training tutorial on the principles of flight
 - Session 3: Spatial aptitude and verbal aptitude measures
 - Session 4: Knowledge test

- Session 3 (about 20 minutes):
 - A spatial aptitude test will evaluate your ability to mentally rotate objects
 - A verbal aptitude test will measure your vocabulary knowledge



Principles of Flight Training – Experiment Briefing



- This experiment is divided into four sessions
 - Session 1: Biographical data and Color Vision Test
 - Session 2: Training tutorial on the principles of flight
 - Session 3: Spatial aptitude and verbal aptitude measures
 - Session 4: Knowledge test
- Session 4 (about 40 minutes):
 - A knowledge test will be given to you, which is divided into four parts:
 - (a) Two concept association measures
 - (b) A recognition multiple choice test
 - (c) A declarative multiple choice test
 - (d) An integration multiple choice test



Principles of Flight Training – Experiment Briefing



- Overall, this experiment should not take more than two hours to complete when counting briefing, breaks, and debriefing time
- If you have any questions, please ask your experimenter now
- When you are ready to proceed, please click on the **green arrow**

Please, turn off or silence all electronic devices to prevent you from being distracted during this experiment.



APPENDIX S:
BIOGRAPHICAL QUESTIONNAIRE

Slide 1

Please complete the following questions. Any information you provide is voluntary and will be kept strictly confidential. A participant number will be assigned to your responses and in no way will your name be associated with the data. The information you provide will be used only for the purpose of this study. If you have any questions, please ask your experimenter.

CLICK ON CONTINUE (BOTTOM RIGHT OF THE SCREEN) TO PROCEED

Continue ▶

Slide 2

Age:

Press ENTER when you have typed your answer

◀ Go Back

Continue ▶

Slide 3

Gender:

- Female
- Male

[◀ Go Back](#)

[Continue ▶](#)

Slide 4

Handedness:

- Right-handed
- Left-handed
- Ambidextrous

[◀ Go Back](#)

[Continue ▶](#)

Slide 5

GPA:

Press ENTER when you have typed your answer

◀ Go Back

Continue ▶

Slide 6

Year in school:

- Freshman
- Sophomore
- Junior
- Senior
- Graduate

◀ Go Back

Continue ▶

Slide 7

Major:

Press ENTER when you have typed your answer

◀ Go Back

Continue ▶

Slide 8

Native language:

Press ENTER when you have typed your answer

◀ Go Back

Continue ▶

Slide 9

Do you have a prescription for glasses or corrective contact lenses?

- Yes
- No

◀ Go Back

Continue ▶

Slide 10

If yes, are you wearing them now?

- Yes
- No
- N/A

◀ Go Back

Continue ▶

Slide 11

Using the scale below, please indicate how would you rate your familiarity with Microsoft Flight Simulator

- | | |
|---|---------------------|
| 1 | Not at all familiar |
| 2 | |
| 3 | |
| 4 | somewhat familiar |
| 5 | |
| 6 | |
| 7 | very familiar |

[← Go Back](#)

Slide 12

Using the scale below, please indicate how would you rate your familiarity with airplane instruments

- | | |
|---|---------------------|
| 1 | Not at all familiar |
| 2 | |
| 3 | |
| 4 | somewhat familiar |
| 5 | |
| 6 | |
| 7 | very familiar |

[← Go Back](#)

Slide 13

Using the scale below, please indicate how would you rate your familiarity with airplane dynamics

- 1 Not at all familiar
- 2
- 3
- 4 somewhat familiar
- 5
- 6
- 7 very familiar

[◀ Go Back](#)

Slide 14

Have you ever participated in any other multimedia training on the principles of flight before?

- Yes
- No

[◀ Go Back](#)

[Continue ▶](#)

Slide 15

If you replied 'yes' at the previous question please describe in what context you're familiar with flight training. If you replied 'no' then write 'N/A'.

Press ENTER when you have typed your answer

[◀ Go Back](#)

[Continue ▶](#)

Slide 16

Thank you for completing this questionnaire. Next, you will complete a color vision test.

[◀ Go Back](#)

[Continue ▶](#)

APPENDIX T:
CBT DEBRIEFING

Slide 1



Principles of Flight Training – Experiment Debrief



- Thank you for your participation in our experiment!
- In this experiment we have manipulated how the information in your training tutorial was presented to you. Specifically, we have two manipulations:
 - *Temporal contiguity*
 - *Color coding*
- Temporal contiguity
 - *Simultaneous group*: in this group participants viewed text and images together
 - *Sequential group*: in this group participants viewed text, followed by images
- Can you tell which group you were in? Ask your experimenter if you need to

Slide 2



Principles of Flight Training – Experiment Debrief



- Thank you for your participation in our experiment!
- In this experiment we have manipulated how the information in your training tutorial was presented to you. Specifically, we have two manipulations:
 - *Temporal contiguity*
 - *Color coding*
- Temporal contiguity
 - *Hypothesis*: we hypothesized that participants in the simultaneous group would be facilitated in their acquisition of instructional material

Slide 3



Principles of Flight Training – Experiment Debrief



- Thank you for your participation in our experiment!
- In this experiment we have manipulated how the information in your training tutorial was presented to you. Specifically, we have two manipulations:
 - *Temporal contiguity*
 - *Color coding*

- Color coding
 - *Paired color-coding*: in this group participants were shown corresponding text and image concepts with the same color
 - *Non-paired color-coding*: here participants had corresponding text and images painted with a different color
 - *No color-coding*: corresponding text and images were not color coded

Slide 4



Principles of Flight Training – Experiment Debrief



- Thank you for your participation in our experiment!
- In this experiment we have manipulated how the information in your training tutorial was presented to you. Specifically, we have two manipulations:
 - *Temporal contiguity*
 - *Color coding*

- Color coding
 - *Hypothesis*: we think that participants in the paired color-coding group will be facilitated in learning the corresponding text and images; thereby, improving what is known as dual-coding



Principles of Flight Training – Experiment Debrief



- If you would like more in-depth explanations about specific hypotheses, expected interactions, or measure rationale, please send us an email via the SONA system, or write me directly at sscielzo@ucf.edu
- Your experimenter will give you a ‘*Psychology Research Experience Evaluation Form for Participants*.’ Please fill-out and return this form as soon as you can to the Psychology Department Main Office (Psychology Building – 3rd floor)
- Your extra-credit will be attributed to you automatically within 48 hours
- If you have problems seeing your extra-credit, please contact us via SONA
- Thank you again for your participation! We hope that you will now have a deeper understanding of aviation basics; but please, don’t go out and fly planes just yet 😊

APPENDIX U:
INSTITUTIONAL REVIEW BOARD APPROVAL FORM



University of Central Florida Institutional Review Board
Office of Research & Commercialization
12201 Research Parkway, Suite 501
Orlando, Florida 32826-3246
Telephone: 407-823-2901, 407-882-2901 or 407-882-2276
www.research.ucf.edu/compliance/irb.html

Notice of Expedited Initial Review and Approval

From : UCF Institutional Review Board
FWA00000351, Exp. 5/07/10, IRB00001138

To : Sandro Scielzo

Date : September 05, 2007

IRB Number: SBE-07-05162

Study Title: **INVESTIGATING THE RELATIONSHIP BETWEEN REFERENTIAL CONNECTIONS AND LEARNING IN A MULTIMEDIA COMPUTER-BASED TRAINING ENVIRONMENT: THE IMPACT OF TEMPORAL CONTIGUITY AND COLOR-CODING ON KNOWLEDGE ACQUISITION**

Dear Researcher:

Your research protocol noted above was approved by expedited review by the UCF IRB Vice-chair on 9/5/2007. The expiration date is 9/4/2008. Your study was determined to be minimal risk for human subjects and expeditable per federal regulations, 45 CFR 46.110. The categories for which this study qualifies as expeditable research are as follows:

6. Collection of data from voice, video, digital, or image recordings made for research purposes.

7. Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.

The IRB has approved a consent procedure which requires participants to sign consent forms. Use of the approved, stamped consent document(s) is required. Only approved investigators (or other approved key study personnel) may solicit consent for research participation. Subjects or their representatives must receive a copy of the consent form(s).

All data, which may include signed consent form documents, must be retained in a locked file cabinet for a minimum of three years past the completion of this research. Any links to the identification of participants should be maintained on a password-protected computer if electronic information is used. Additional requirements may be imposed by your funding agency, your department, or other entities. Access to data is limited to authorized individuals listed as key study personnel.

To continue this research beyond the expiration date, a Continuing Review Form must be submitted 2 – 4 weeks prior to the expiration date. Advise the IRB if you receive a subpoena for the release of this information, or if a breach of confidentiality occurs. Also report any unanticipated problems or serious adverse events (within 5 working days). Do not make changes to the protocol methodology or consent form before obtaining IRB approval. Changes can be submitted for IRB review using the Addendum/Modification Request Form. An Addendum/Modification Request Form cannot be used to extend the approval period of a study. All forms may be completed and submitted online at <http://iris.research.ucf.edu>.

Failure to provide a continuing review report could lead to study suspension, a loss of funding and/or publication possibilities, or reporting of noncompliance to sponsors or funding agencies. The IRB maintains the authority under 45 CFR 46.110(e) to observe or have a third party observe the consent process and the research.

On behalf of Tracy Dietz, Ph.D., UCF IRB Chair, this letter is signed by:

Signature applied by Joanne Muratori on 09/05/2007 10:14:43 AM EDT

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