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Visual Learning Styles Among Digital Natives

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VISUAL LEARNING STYLES AMONG DIGITAL NATIVES

A Thesis

Submitted to the Faculty

of

Purdue University

by

Eric W. Palmer

In Partial Fulfillment of the

Requirements for the Degree

of

Master of Science

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Purdue University

West Lafayette, Indiana

For my parents, who have always encouraged me to challenge myself.

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ABSTRACT

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This study explored the concept of digital nativity and its educational implications, including application of the learning styles hypothesis. The concept of digital natives, first put forth by Marc Prensky, introduced the notion that individuals raised in a technological environment have developed in such a way as to utilize information differently than the non-native generations before them. This study examined the possibility that these differences may include an increased efficiency in the utilization of narrative imagery versus textual information. The potential benefit of utilizing narrative imagery as an instructional tool is discussed. An experimental test application was developed for the purpose of identifying any relevant learning trends among the digital native subject pool tested in this study. The results of this experiment were statistically analyzed to reveal the significance of the research. This analysis suggested a possible trend toward multimodal learning styles in the subject pool as well as indicating that digital natives may in fact utilize visual information more efficiently than textual information, reducing the training time requirement by nearly half.

CHAPTER 1 INTRODUCTION

This chapter provides an overview of the research objective. It also establishes the scope of research by outlining the research question, purpose, significance, assumptions, limitations, and some definitions relevant to the research.

1.1. Objective

The objective of this research was to identify and confirm the prevalent learning styles or capacities among members of the “digital natives” group. This objective merged computer graphics technology with educational psychology. Relevant study areas include graphical user interfaces, “digital native” learning styles, “narrative imagery,” semiotics, memory, and sign systems.

1.2. Research Question

What is the effect of a media-based, visually-oriented educational system on the time required to learn a technical procedure for digital natives relative to their apparent learning style preferences?

1.3. Statement of Purpose

The purpose of this research was to discover the educational capacity of visual learning tools within media devices relative to their largely text-based counterpart, traditional training materials, for “digital natives.” Training methods such as textbooks are potentially an inefficient teaching method when utilized by members of the “digital natives” group. The intent of the study was to produce data demonstrating that by using appropriate imagery as the primary

communicator, ideas may be conveyed in shorter periods of time and produce equivalent or better training outcomes for “digital natives.”

1.4. Significance

The significance of this research was in finding further evidence of “digital native” learning styles or capacities, specifically in support of hypotheses relevant to “digital natives” and “narrative images” and the interrelation of these concepts. This study endeavored to discover instructional efficiency differences in learning materials for “digital natives,” specifically in an attempt to reduce training time by half while maintaining equivalent results. The outcome of this evidence could be greater recognition of the changing learning styles of the target population and increased knowledge of the specific ways in which they are being altered.

1.5. Assumptions

The following assumptions were made in this study:

1. Subjects appropriately qualified as members of the “digital native” group when being utilized as part of that sample
2. The answers provided in the exit survey provided appropriate details for categorizing subjects
3. Test performance accurately reflected the true resultant training outcomes in the subjects relative to instructional differences of the visually-oriented education system versus the text
4. Hoffman’s rules of visual perception were adequate for construction of visual information
5. Visual elements constructed for the experiment correctly followed Hoffman’s rules of visual perception
6. The VARK questionnaire, a learning style preference assessment tool developed by Neil Fleming, appropriately identified learning style preferences for the purposes of this study

1.6. Limitations

The following limitations were present in this study:

1. The student sample was limited to the available number of volunteer participants at the Purdue University campus in West Lafayette, Indiana
2. The measurements of interest were limited to the data recorded by the media-based testing device
3. The study was limited to the experimentation semester of spring 2011

1.7. Delimitations

The following delimitations were present in this study:

1. This study was not intended to analyze the differences in learning styles between members of generation X and generation Y, nor between males and females, nor between peoples of various cultures
2. Information collected during experimentation via exit survey was used for the purpose of secondary observations with the intent to corroborate previous research and help direct future research
3. Results of the VARK questionnaire were used to determine learning style preferences according to the VARK model
4. Results of the survey were used to determine potential digital native status
5. Population sample utilized restricted results to being applicable to the Computer Graphics Technology department at Purdue University

1.8. Definitions

Cognitive Apprenticeship – Educational process that mimics the stages of knowledge building as seen in the transfer of knowledge from a master to an apprentice (Brown, Collins, & Duguid, 1989).

Digital Native – Members of this group were raised in a technological environment (regular exposure to digital devices from childhood); they

display increased reliance and ability with technological devices (including frequent usage in daily life); generation Y of the developed nations begin to embody this definition (Prensky, 2001).

Generation Y – Generally accepted to consist of those born during the 1980's and into the mid-1990's, with some opinions extending that range a few years in either direction (Black, 2010; Heckman, 1999; Mumford, 2006).

Narrative Image – Symbols and visuals used in place of words to communicate concepts (Black, 2010).

Semiotics – Study of sign processes and communication (Bouissac, 2007).

Sign System – Set of linguistic conventions by which meaning is conveyed and understood (Bouissac, 2007).

1.9. Summary

This chapter has provided an overview of this study, including the scope of the research, the purpose and significance of the study, and some definitions to provide context necessary for understanding the remainder of this document. The next chapter describes studies, applications, and theories relevant to this study.

CHAPTER 2 REVIEW OF RELEVANT LITERATURE

2.1. Visual Learning

2.1.1. Introduction

Technology is already recognized as a powerful tool for education when it can be properly employed (Chen, 2010). The technological challenge for education and training today is the development of appropriate applications within appropriate media. Current delivery methods restrain students or trainees by requiring large amounts of computer equipment, may be heavily text-based, or often are a one-way channel of information without the interactivity that can benefit the learning process (Chan, Miller, & Monroe, 2009; Cherrett, Wills, Price, Maynard, & Dror, 2009).

2.1.2. Pictorial Information

The selection of a communicative device, in this case referring to technique rather than technology, is an important one. Graphical symbols have been identified as having strong communicative and educational properties. If one considers the earliest writings to actually be drawings—images rendered on cave walls by prehistoric humans—these drawings would be examples of the first visual communications created by humanity. Many early writing systems consisted of pictorial characters, such as Egyptian hieroglyphics or ancient Sumerian writing before the evolution of cuneiform script (Cassidy, 2002). Even modern typography can be considered a form of graphical symbol system. The capacity of the written word to convey ideas is demonstrated in the reading of this paper. When typography is utilized as a graphical symbol, the messages and meaning conveyed can be altered or enhanced (Drucker, 2008). However, while

typography provides a method for the communication of complex ideas, it is not without its limitations. All communication requires a context for understanding. The use of more pictorial sign systems has the capacity to provide a greater base upon which to build this context, where other limitations such as language, vocabulary, or certain deficiencies could impede the communication. Locations such as international airports have signs composed of symbols rather than words marking a wide range of important locations and instructions. Graphical symbols can be utilized to overcome language barriers (AIGA, 2010), communicative impairments or deficiencies (Bailey & Downing, 1994), or even the developmental stages of an infant in the case of a study done at Purdue University (Da Fonte, 2008) wherein infants were able to indicate preferred food items using symbols. Representation of information in the pictorial form enables this effective and efficient means of communication, accessing a broader context through these non-verbal representations.

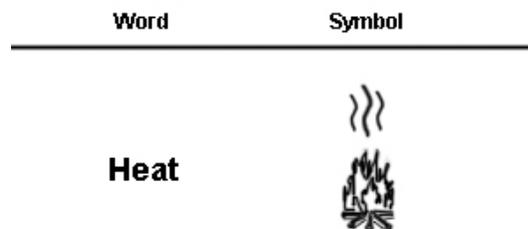


Figure 2.1. Example of a word and its possible symbol.

2.1.2.1. Graphical User Interfaces

In terms of technology usage, graphical user interfaces have been shown to have the capacity to convey multiple messages at once, such as potential actions combined with the passage of time. For example, the graphical element representing a potential action could “fill” with color to indicate the passage of

time until that action can be taken. The action as well as the time at which it can occur are both represented simultaneously in the same graphical user interface element. Utilizing the graphical interface in this way, the temporal aspect of the application can be incorporated into the interaction, conveying ideas such as how long the action lasts, what limitations may exist, or how the action can be repeated (Mitchell & van Sommers, 2007). This is one example of the way in which components of graphical interfaces can take on similar functioning to components of language, in this case performing the role of indicating time or tense (Clark, 1973; Traugott, 1975)

2.1.3. Learning Styles and Narrative Imagery

A learning style is an approach to learning or an educational method utilizing a specific type of stimulus. There exists a number of learning style models, each presenting a different assortment of learning style preferences. Beyond a mere stated preference for how new information is received, the learning-styles hypothesis is a claim that learning is less efficient or effective if learners do not receive instruction that accounts for their learning style (Pashler, McDaniel, Rohrer, & Bjork, 2008). The assumed outcome of this claim, if true, is that if instruction is matched to the learner's preferred style then a better result can be achieved. Thus if a learner preferring visual instruction receives new information in a pictorial form, the hypothesis would suggest that this would result in greater learning than would the same learner with information in another form, such as text, or another learner with a different learning style preference, such as for auditory presentation (Fleming, 1995).

2.1.3.1. VARK

A commonly used learning styles model devised by Neil Fleming of Lincoln University, the VARK stands for Visual, Aural, Read/Write, and Kinesthetic learning styles. The visual component refers to the individual's preference to learning material composed of diagrams, symbols, shapes, patterns, and other pictorial information. The read/write component is a

preference to textual information and is the most common method of instruction used in Western culture (Fleming, 1995). Aural presentation is received through auditory input such as lectures. The kinesthetic approach refers to a preference to learn by performing actions. When an individual has more than one learning style preference, it is considered a multimodal preference. Within the educational populations typically sampled by the VARK database—populations similar to the sample analyzed in this study—the distribution of learning styles according to the recorded VARK data as of September 2010 is represented in Table 2.1.

Table 2.1
VARK database results (n = 76252; September 2010)

Learning Style Preference	Population Percentage
Visual	3%
Aural	8%
Read/write	13%
Kinesthetic	13%
Multimodal	63%

Dr. Walter Leite from the Research and Evaluation Methodology program of the University of Florida has conducted a study to validate the VARK model and questionnaire. The study makes note of some of the limitations of the VARK and offers adequate evidence for the reliability of the questionnaire for the purpose of this study (Leite et al., 2010).

2.1.3.2. Digital Natives

Generation Y, or “Gen Y,” is generally accepted to consist of those born during the 1980’s and into the mid-1990’s, with some opinions extending that range a few years in either direction (Black, 2010; Heckman, 1999; Mumford, 2006). Gen Y is seen as the tech-savvy, gamer generation that was raised in a world dominated by digital technology and information. Additionally, this generation that was born into technology is incredibly adept at utilizing such

devices and digital information. Some experts, such as Dr. Anders Sandberg and Nick Bostrom of Oxford University and Helen Petrie of the University of York, suggest that exposure to technology from such an early age has had a “rewiring” effect on the brain when compared to those who were not raised in a technological environment: various digital stimuli may have affected the neurological development or the evolution of neural networks (Woods, 2006). Marc Prensky coined the term “digital native” to describe individuals who fit this description. This digital environment may be providing many more opportunities for abstract thinking early in life. It is possible that the human brain’s digital input has altered the development of these neural networks, changing the means by which these individuals learn and think because they are physiologically different from those who were raised in a non-digital environment (Prensky, 2001). These “digital natives” perceive and sift through information better, and naturally filter out extraneous details by virtue of having been reared in a media-rich, interactive digital world (Black, 2010).

2.1.3.3. Narrative Images

Additional research indicates that digital native mental processes work in narrative images, with symbols and other imagery taking the place or at least being used in conjunction with text (Black, 2010). The suggestion here is that the indicated population, when given the opportunity, has the tendency to access information first through imagery and then possibly use text or some other reference to clarify the meaning. An example application of this knowledge would involve the graphical reference, representing some portion of information or action, being the primary element while the clarification of this reference would be provided by tooltip or other on-demand means. This concept is already prevalent in user interface design, as can be seen in most computer applications where the majority of basic operations are represented by buttons with icons that indicate their function. Interfaces designed with this in mind could potentially be operated as “second nature” to digital natives. Another example of this functioning is demonstrated in Allan Paivio’s dual-coding theory, which suggests

that imagery is encoded as analogue perceptual information. This channel of information operates separately from the abstract representations of the channel that receives verbal information such as text (Paivio, 1986).

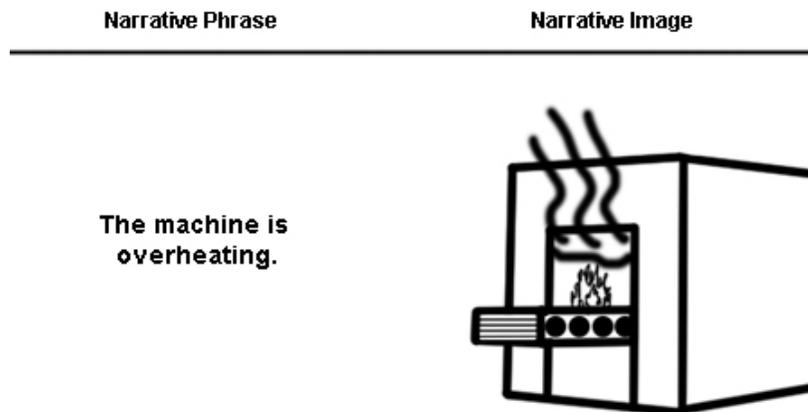


Figure 2.2. Example of narrative imagery.

2.1.3.4. Line Drawings

The features of a pictorial are significant to its ability to function as a narrative image. Properly created line drawings can be used to convey sufficient information to allow the observer to construct the necessary information within the perception of the image. According to Hoffman's rules of perception, there is a system of processes that the human mind goes through to generate meaning from even simple line drawings (Hoffman, 1998). The rules of these self-constructions can be used to simplify the information presented and allow proper attending without excess distraction to the conveyed message in the drawing.

One of the most critical elements in the construction of line drawings is the depth cuing. Depth cues are details in the line drawing that appeal to one or more of Hoffman's rules of visual perception to direct the observer to construct three-dimensional detail out of the two-dimensional image. An example of a

depth cue would be an overlapping line entering the perimeter of a circle with the continuation of the line on the opposite side not overlapping to indicate a three-dimensional nature to the circle, being in fact a spherical structure. In a study published by the *British Journal of Psychology*, it was discovered that the secondary depth cues, including line convergence, overlapping, and relative size, presented in a line drawing resulted in similar understanding to fully rendered images with texture and shadow (Nicholson & Seddon, 1977).

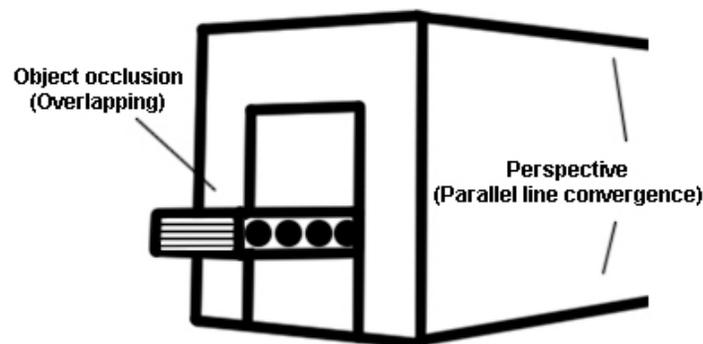


Figure 2.3. Examples of depth cues in a line drawing.

Hoffman's rules also indicate that line drawings can be created in such a way as to direct the observer to construct surfaces in the image. The contours and edges of the surface are all that may be required to prompt the viewer to see surfaces, even when the surface may be curved. In a paper published in *ACM Transactions on Graphics*, the best line drawings resulted in test subjects being able to successfully orient gauges to the direction of the surface they were intended to construct (Cole, Sanik, DeCarlo, Finkelstein, Funkhouser, Rusinkiewicz, & Singh, 2009).

A line drawing created following Hoffman's rules of perception may still contain ambiguity in some details. In the event that an important aspect is not correctly perceived by all observers, a labeling format can be utilized to remove the remaining ambiguity. In a study reported in the *International Journal of*

Computer Vision, a labeling system was devised for indicating the details of a line drawing in order to prevent any potential ambiguity in the construction (Parodi, 1996).

2.2 Pervasiveness of Technology

As technological devices become more commonplace and are developed for greater ranges of functionality, their integration into many daily activities is an inevitable factor in modern society. These devices rely upon a number of factors that influence their ability to provide useful functionality. This section elaborates on some of these aspects and how they contribute to the usage of technology in various settings.

2.2.1 Technology as an Extension of Human Cognition

Marshall McLuhan's environmental thesis suggests metaphorically that technology surrounds and influences human culture in the same way that water surrounds and influences fish – sometimes almost unnoticeable in nature, but increasingly essential for our continued existence in a technologically-enhanced society (McLuhan, 1964). Technological media acts as an extension of the human body, or more accurately an extension of human cognition, bringing forth sensory input that would otherwise elude the individual and at the same time partly controlling how that input is perceived. The medium should be an almost invisible tool for this perception. The less the medium constrains the usage of the application, the more easily that usage can flow into standard activities (O'Neill, 2008).

2.2.1.1 Portable Media Devices

An important step toward expanding the usefulness of the medium is enhancing the portability of the device. As digital applications become more desirable in everyday activities such as education, making the devices that run those applications more practical for teachers and students to use conveniently is

essential to allowing those individuals to speak the same technological “language” (Prensky, 2001). Advancing technology is providing an opportunity for people to take their technology with them wherever they go, no longer being chained to their desks and large desktop computers. Portable media players, smartphones, portable keyboards, small laptops, tablet PCs, and PDAs can all be utilized to create, store, and access a wide range of digital information from a variety of locations. These types of technologies are already beginning to establish a foothold in the classroom. Teachers are finding various methods of using these devices to enhance their instruction, from as simple as recording a lecture as an audio podcast that can be replayed at any time to full mobile work labs (Doe, 2006).

2.2.2 Semiotics and Memory

Semiotics is the study of sign processes and communication. Studies in semiotics can include the iconicity and symbolism of a sign, such as for the globalization of information based on cultural conventions. For instance, a letter-based logo can become more of a symbol and less an icon when communicated between cultures. This is one example of how semiotics shows that the usage of sign systems is reliant upon context (O’Neill, 2008). As such context primarily relates to memory, sign systems can be said to be reliant upon memory. The meanings associated with the parts of a sign system are recalled from memory to assign value to the message (Bouissac, 2007). This is the reason why context is a necessary part of communication. Likewise familiar context may be utilized to aid in the learning of new material, forming a sort of “two-way street” of contextual memory.

2.2.3 Evolution of Interactive Computers: Culture and Sign Systems

In terms of education technology, the focus generally falls on the communicative aspects of the technology – the type of information that can be displayed, how the information is presented, and the methods by which that information can be affected or influenced. The evolution of computers as

communicative media has resulted in a variety of forms and functions – from large desktop computers to tiny cell phones. This evolution has not only been the result of computational advancements but also the cultural drive to assimilate new technologies (O’Neill, 2008). At the simplest level, this pairing of culture and technology requires two elements: convenience of usage and a sign system relevant to the context of that usage. Convenience of usage is generally related to the portability of the device being used; however, this can also refer to the usability of the digital application being run on the device. This concept directly relates to the usage of a relevant sign system. Sign systems in semiotics are sets of linguistic conventions by which meaning is conveyed and understood (Bouissac, 2007). The more relevant the presented information is to the context of the learner, the greater the resulting engagement will be. Greater engagement has the potential to enhance the educational properties of the application and result in more effective communication and training outcomes.

2.3 Technological Enhancement of Learning

Computers and other devices have been included in educational and training environments for decades. Recently, as the necessary technology has become more commonplace and affordable, technology has been incorporated into learning situations more and more frequently. This section describes some of the established connections between technology and education.

2.3.1 The Changing Landscape of Education and Training

The generation currently entering the workforce and secondary education (“Gen Y”) is a generation becoming increasingly dependent upon technology (Prensky, 2001). The technological environment in which they were raised leads them to strive to utilize technology in their daily lives to enhance their normal activities. This may indicate that future learning may not only benefit from the use of proper technology, but technology-based education may even exceed the effectiveness of traditional teaching methods (Black, 2010; Chen, 2010; Doe,

2006). This dependence on technology that Gen Y possesses is not as much a negative as it is an evolutionary step of humanity's mastery of its environment (Prensky, 2001).

2.3.2 Cognitive Apprenticeship

Electronic cognitive apprenticeship is a training strategy already being employed that utilizes technology (Chen, 2010). In one example of this method, the apprenticeship is carried out by an application on a training workstation, presenting a collection of instructional videos that the learner can watch, followed by quizzes and checklists to confirm the information has been received. In one case, the resulting use of this system cut the example company's training time by half with equivalent results to standard training (Chan et al., 2009). Cognitive apprenticeship shows that technology has the capacity to provide a means of effective and efficient training, even independent of additional instruction. Achieving equivalent results to standard training in approximately half the time is a significant efficiency objective identified in literature such as this.

2.3.3 Enhancing Learning through Hypermedia

Research has shown that interactive and graphically rich elements can also enhance the learning process (Black, 2010; Cherrett et al., 2009). For example, instead of simply playing a video from beginning to end, an application allowing the learner to click an element of the video for more information, provided by a graphic or text, introduces an on-demand digital teaching method. Enabling the learner to engage in an inclusive digital learning experience allows the learner to directly interact with the training medium. The resultant learning environment can have the capacity to increase an individual's ability to transfer information from the short-term to long-term memory (Cherrett et al., 2009). Other forms of hypermedia may be equally beneficial; however, the focus remains on enabling the learner to direct the flow of knowledge being sought to best utilize the educational effort.

2.4 Summary of Literature Review

It is the intention of this paper to further analyze the benefit of visual learning through a media device by digital natives. The research presented in this literature review has examined the communicative and educational properties of visual information in technology. It has also shown that individuals currently entering the workforce and secondary education belonging to the digital natives group tend to process information in narrative images, working better with pictorial representations rather than large amounts of text. Portable media devices capable of merging into standard activities aid the convenience of usage of graphical applications in everyday life. These graphical applications should utilize appropriate sign systems for proper contextual reference to the learner. Finally this changing landscape of learning may benefit greatly from the evolution of cognitive apprenticeship through technology, embracing greater degrees of interactivity and engagement to produce more effective educational and training outcomes.

CHAPTER 3 METHODOLOGY

The purpose of this research was to discover the educational capacity of visual learning tools within media devices relative to their largely text-based counterpart, traditional training materials, for digital natives. This chapter outlines the methodology of this research, including the study design, sampling design, and units of measurement and analysis.

3.1 Participants

The targeted population was the digital natives group, typically of generation Y. A sample was drawn from the Computer Graphics Technology department at Purdue University. The sample population consisted of 28 individuals split by ID number between the textual (version A - 13 subjects, odd IDs) and narrative image (version B - 15 subjects, even IDs) testing groups. The Purdue student sample was drawn from the Computer Graphics Technology department in the experimentation semester of spring 2011.

Table 3.1
Subject demographics (See Appendix C for listing of each subject)

Version	Male	Female	Birth year range
Text	10	3	1988-1992
Narrative image	14	1	1984-1992

3.2 Materials

The materials used in this study included the VARK questionnaire, the Digital Natives Training Module, and the survey. See Appendix A for the full

testing procedural instructions given to the subjects, including information on the VARK questionnaire and the survey. The Digital Natives Training Module consisted of a web application that presented the training material for the selected version to the subject followed by the validation test. The training material consisted of the presentation of four conditions of a fictional machine to the subject. Each condition provided a scenario description, either using text or narrative image depending on the selected version, a response appropriate to that condition, and a geometric shape to serve as a representative symbol of that condition. See Appendix B for the narrative images and conditional symbols chosen for each scenario. The narrative images displayed in Appendix B were placed next to the conditional symbols on the instructional pages of version B of the Digital Natives Training Module web application. Table 3.2 provides reference for the design of the instructional materials. Following the training, all subjects proceeded to an identical test consisting of four questions presenting each of the four conditional symbols and asking the subject to select the proper action from a multiple choice list of all four responses. Each test question stated the name of the symbol being indicated on the machine and displayed an image of that symbol.

Table 3.2
Digital Natives Training Module assets

Condition	Asset	Version A	Version B
Overheat	Text	If the machine is producing too rapidly, it may result in overheating. When the machine displays a square, this indicates that it is overheating and needs to be slowed down.	When the machine displays a square, this indicates that it is overheating and needs to be slowed down.
	Symbol	Square	Square
	Narrative image	N/A	See Appendix B

Table 3.2 (continued)

Digital Natives Training Module assets

Jammed	Text	If the machine gets a part stuck in the belt, this may damage the machine. When the machine displays a triangle, this indicates that it is jammed and the belt needs to be cleared.	When the machine displays a triangle, this indicates that it is jammed and the belt needs to be cleared.
	Symbol	Triangle	Triangle
	Narrative image	N/A	See Appendix B
Continue	Text	If the machine produces a part without any problems, the machine can proceed to the next part. When the machine displays a circle, this indicates it should continue to the next part.	When the machine displays a circle, this indicates it should continue to the next part.
	Symbol	Circle	Circle
	Narrative image	N/A	See Appendix B
Stop	Text	If the machine encounters a serious problem that cannot be solved easily, the machine should be stopped. When the machine displays a star, this indicates it should be stopped.	When the machine displays a star, this indicates it should be stopped.
	Symbol	Star	Star
	Narrative image	N/A	See Appendix B

3.3 Measures

Data for the quantitative analysis was acquired by the testing device – a media application that delivered the training materials for both methods as well as a test application for the purpose of testing the procedural knowledge acquired during the training phase. This application recorded subject input and time elapsed for the purpose of quantifying training time required and accuracy of the training. The application recorded time on task per page within the training materials of the module to a hundredth of a second. The validation test checked for accuracy of the learned material, recording whether the subject answered each of the four questions correctly. These measures were compared in the analysis to determine apparent differences of training methods for the two groups of subjects. The hypothesis suggested in the literature that training time for narrative imagery subjects could be reduced by as much as half that of the text subjects while maintaining equivalent accuracy was the objective set for this study.

Data for the analysis of digital native status and learning style preference was acquired by exit survey and VARK questionnaire. These measures were intended to obtain information on subject opinions and feelings about the usage of the training tool, as well as to categorize the subject as a digital native. This data was used for the purpose of determining if subjects felt the training tool was both useful and usable and whether they felt it would be helpful to use the device for learning other processes in the future. See Appendix A for the survey questions. The VARK questionnaire was utilized to establish the subject learning style. The VARK outputs a series of four numbers, each one associated with one of the learning style preferences of the VARK model.

3.4 Procedure

This study was a quantitative analysis endeavoring to determine the relative educational benefit of utilizing visual information over text. The study also

had a survey component with the intent to gauge subject opinions on using the device and learning technique. Through the survey, the subject identified himself or herself as a digital native or otherwise. Additionally, the VARK questionnaire was used to establish the subject learning style.

Subjects were presented with a media presentation of training materials through the Digital Natives Training Module. Subjects were placed into one of two groups. One group (version A) was presented with textual information describing the condition scenario. The other group (version B) was presented with a narrative imagery presentation of the same information. The text-based method utilized primarily text descriptions to instruct the subject in the performance of the technical tasks. Text was selected over aural or kinesthetic information due to its prominence in Western instruction, as Neil Fleming has discussed in his talks on learning styles. The alternative test method utilized the visually-oriented, narrative imagery training. See Appendix B for the imagery used in the training materials. The instructional pages were accessible in any order, allowing the subject to engage in self-guided learning of the selected technical process. Subjects were tested by performing the instructed tasks following the training.

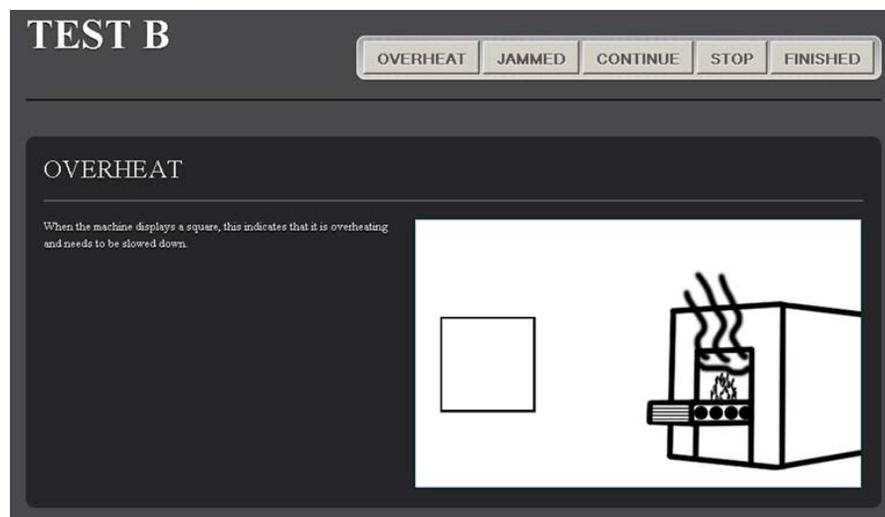


Figure 3.1. Example training material from version B of the module.

The technical process learned in the training was the operation of a fictional machine. The training was accomplished by the Digital Natives Training Module, a media application constructed for this experiment. The fictional machine had four states (overheated, jammed, ready to continue, or needing to be stopped), each assigned an arbitrary geometric shape to represent that state. The symbol and the state were presented similarly in both versions. The descriptive information that presented the scenario of each state to the subject was given by text description in one version and narrative imagery in the other.

Following the completion of the training to the subject's satisfaction, the subject was tested for knowledge gained of the fictional machine's operation. A series of four multiple choice questions presented the subject with each of the machine's conditional symbols and required the subject to recall what operation should be performed in response to the situation. Figure 3.2 provides a visual description of the testing procedure. See Appendix A for the complete instructions given to the test subjects.

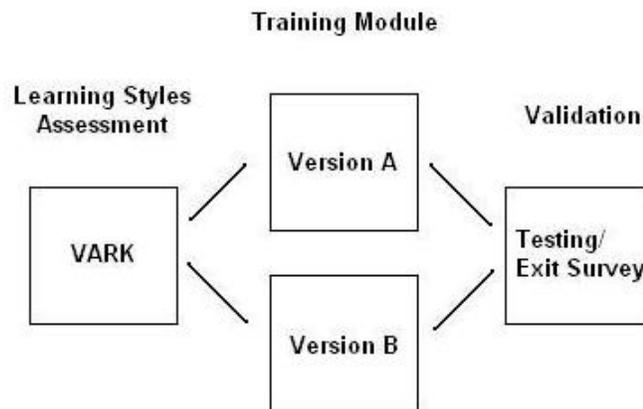


Figure 3.2. Subject testing procedure flowchart.

3.5 Analysis

The analysis for the data collected in this study was designed to compare the training time requirement of the two instructional versions and validate that result by the test accuracy. The training time was compared by an analysis of variance statistical analysis. Another analysis of variance was conducted to compare version A and version B discriminating by all learning style preferences. This analysis divided the subjects into seven data categories, one for each version and learning style. An analysis was performed comparing subjects that indicated visual preference, including multimodal preferences that incorporated visual, against all other subjects. This analysis divided the subjects into four categories: version A with visual preference, version A without visual preference, version B with visual preference, and version B without visual preference. An additional analysis of variance compared subjects that indicated multimodal preference against all other subjects. This analysis divided the subjects into four categories: version A with multimodal preference, version A without multimodal preference, version B with multimodal preference, and version B without multimodal preference.

The VARK was analyzed automatically by the questionnaire. The digital native qualification questions in the survey were analyzed according to the definitions provided in the literature regarding what constitutes digital native status. The answers that indicate digital native status are as follows: usage of digital devices “several times a day,” usage of digital devices since “early childhood,” and a self-competency assessment of being a “techno-pro.” Subjects selecting either all three of these answers, or any two plus the next closest answer on the third question, qualified for digital native status. The Digital Natives Training Module and survey were validated prior to testing by a pilot study that produced results that matched expectations based on the literature of this research.

3.6 Summary

This chapter presented the study design, sampling, and units of analysis used in this research. The primary hypothesis of this study was that the narrative imagery test group would result in training time approximately half that of the text test group while maintaining equivalent accuracy results. The following chapter presents the data resulting from this experiment.

CHAPTER 4 RESULTS

This chapter presents the results from the experimentation of this study, including the statistical analysis of the training time comparison, in a factual and numerical fashion. The conclusions drawn from this information can be found in the next chapter.

The results from this study can be divided into three sets. The first set is the quantitative results from the web application experimental training module. The second set is the results from the VARK questionnaire. The third set is the results from the exit survey.

4.1 Digital Natives Training Module

Data sets for 28 subjects were collected for this study. Of the collected data sets from the Digital Natives Training Module, 13 subjects used training version A (text) and 15 subjects used training version B (narrative imagery). Three of the subjects from training version B omitted at least one of the training pages, invalidating those results and causing them to be removed from the data set. See Appendix C for a full listing of the quantitative results of the study.

An analysis of variance (ANOVA) statistical assessment was run on the remaining 25 data sets to establish the difference in training time between groups being based on the presented instructional material. On each version's knowledge validation test results, two of the subjects failed by accuracy, having missed at least two of the four questions. By validation of this measurement of accuracy of training outcome, the results are comparable. The ANOVA test comparing the training time measured for version A versus version B resulted in a p-value of 0.0079, seen in Table 4.2. The average training time measured for

subjects of version A was 120.62 seconds. The average training time measured for subjects of version B was 69.45 seconds. Table 4.1 shows training time averages per version according to learning style preference. The analysis of variance result of the comparison of version A and version B discriminating by all learning style preferences is shown in Table 4.3. This analysis divided the subjects into the same seven data categories seen in Table 4.1, resulting in a p-value of 0.1506. Table 4.4 shows the analysis performed comparing subjects that indicated visual preference, including multimodal preferences that incorporated visual, against all other subjects. This analysis divided the subjects into four categories: version A with visual preference, version A without visual preference, version B with visual preference, and version B without visual preference. This resulted in a p-value of 0.0732. Table 4.5 displays the analysis of variance comparing subjects that indicated multimodal preference against all other subjects. This analysis divided the subjects into four categories: version A with multimodal preference, version A without multimodal preference, version B with multimodal preference, and version B without multimodal preference. This resulted in a p-value of 0.0227.

Table 4.1

Training time means by training version and learning style preference

Learning Style	Visual	Aural	Read/write	Kinesthetic	Multimodal
Version A	107.45 (n=2; SD=4.95)	103.04 (n=1)	N/A	100.08 (n=4; SD=75.46)	141.64 (n=6; SD=36.68)
Version B	50.65 (n=1)	N/A	N/A	88.59 (n=3; SD=63.25)	64.62 (n=8; SD=29.11)

Table 4.2

ANOVA table for training time differences between version A and version B

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	16338.04884	16338.04884	8.46	0.0079
Error	23	44403.24406	1930.57583		
Corrected Total	24	60741.29290			

Table 4.3
ANOVA table for training time differences between version A and version B
comparing all learning style preferences

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	6	22972.19626	3828.69938	1.82	0.1506
Error	18	37769.09664	2098.28315		
Corrected Total	24	60741.29290			

Table 4.4
ANOVA table for training time differences between version A and version B
comparing visual preference (including multimodal) to other preferences

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	16813.19007	5604.39669	2.68	0.0732
Error	21	43928.10283	2091.81442		
Corrected Total	24	60741.29290			

Table 4.5
ANOVA table for training time differences between version A and version B
comparing multimodal preference to other preferences

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	21819.68298	7273.22766	3.92	0.0227
Error	21	38921.60992	1853.41000		
Corrected Total	24	60741.29290			

4.2 VARK Learning Styles Assessment

The VARK automatically assessed the results of the questionnaire. Seventeen of the VARK questionnaires resulted in an indication of multimodal learning preferences, fourteen of which were usable in the analysis. Eleven of the assessments were inclined toward a single learning style. Seven of the questionnaires rated the kinesthetic learning preference highest. Three of the questionnaires rated visual preference highest; however, including the multimodal preferences, nine data sets that were usable in the analysis indicated

visual among the preferred learning styles. One questionnaire rated aural learning highest. See Appendix C for full listing of VARK results.

4.3 Exit Survey

Thirteen of the subjects indicated the presentation of material was interesting, eight of them being subjects of version B. Twenty-five of the subjects found the material easy to understand. Twenty-four of the subjects found the learning environment to be comfortable. Seventeen of the subjects indicated they would enjoy learning additional material in the future using a similar training module.

4.4 Summary

This chapter presented the resultant data from the study. The statistical assessment performed on the primary hypothesis indicated a significant outcome. The strongest learning style trend in the subject pool was toward multimodal preferences. The final chapter discusses possible explanations and conclusions developed from the data provided in this chapter.

CHAPTER 5 CONCLUSIONS

This chapter provides conclusions and other thoughts drawn from the data presented in the previous chapter. These conclusions include possible reasons for the significant difference in training time between versions, thoughts on the results of the VARK questionnaire and exit survey, and possibilities for future research on this topic. From the subject pool used for this study, these conclusions may be applicable to the Computer Graphics Technology department at Purdue University.

5.1 Significance of the Training Time

The statistical analysis of the difference in training time between the two versions resulted in a significant finding with a p-value of 0.0079 using an alpha level of 0.01 as the determination of significance. The average reduction in training time for subjects of version B (narrative imagery) versus version A (text) of approximately 42.4% approaches the objective set by the original hypothesis, which expected up to a fifty percent reduction while maintaining equivalent accuracy.

Given the mixed results of the VARK questionnaire, an alternative explanation for the significant difference in training time may be needed. It is possible that the capacity for digital natives to utilize narrative images is unrelated to the learning styles hypothesis, or at least the model put forth by the VARK. This will be discussed further in the next section.

The reduction in training time may also be a result of the training content used in the experimental web application. As the text and imagery used to

convey relevant scenario data was not required for the purpose of passing the validation test, it is possible that this information was omitted during training by subjects of version B. However, the subjects were not necessarily aware of this fact during training, so there would seem to be no reason to assume the subjects intentionally omitted any information during training. Additionally, it was equally possible for subjects of version A to omit the same information.

5.2 Thoughts on the VARK Results

It was the expectation of this study to find digital natives utilized narrative imagery more efficiently than text with a hypothesized difference of fifty percent of the training time of the textual instruction. The assumed correlation was to be subject learning styles according to the VARK model. However, this study found no statistically significant correlation with subject learning styles. The sample size used in this study was too small to establish a correlation with so much variability in the VARK results. The analysis did suggest that perhaps with a larger sample size statistical significance could possibly be achieved in the comparison of multimodal learning preferences and perhaps visual preference as well when visual and multimodal preferences that include visual are analyzed.

The VARK model suggested that the majority of subjects in this sample should have a multimodal preference. The strongest trend for learning styles in this subject pool indeed was toward a multimodal preference with seventeen of the twenty-eight subjects indicating this preference. While this is not a trend toward a singular learning style, it may imply that it is not strictly the visual presentation of the narrative imagery that provides the efficient learning opportunity for digital natives, but the combination of media in the presentation that has this effect. Other studies on multimedia presentation and its impact on education have been previously executed related to this concept. Perhaps it is the trend of digital natives toward a multimodal learning style preference rather than a visual preference that has resulted in these outcomes.

5.3 Assessment of the Exit Survey

The results of the exit survey largely indicated the subjects had positive experiences with the training application. The subjects stated in the survey that the instructional material presented in this study was clearly understood and the high accuracy results on the validation test would seem to corroborate this. Most of the subjects of version B indicated that the presentation of material was interesting, which further contributes to the engagement of the narrative imagery presentation. The comfort and ease of use and understanding of the material provided suggest that a similar approach could be taken in future research efforts. Suggestions for those future efforts are discussed in the next section.

5.4 Future Research

Given that the results of this study were significant, but the expected cause was inconclusive, a second study utilizing a subject pool of non-natives (“digital immigrants”) would be prudent. This second study would assist in better defining the differences apparent in digital natives. It would also provide an opportunity to display whether the specific characteristics resulting in the efficiency differences are unique to digital natives versus their digital immigrant counterparts.

Future studies may also benefit from developing more complexity in the training materials. For the purposes of this study, the training materials were greatly simplified in the effort to reduce confounding variables. However, additional complexity in the training materials of future studies may better help to illuminate the differences between subject pools and their utilization of those materials. Ideally the variable information presented in either version should also be required for passing test validation.

5.5 Summary

This chapter discussed the conclusions and possible explanations for the data gathered from the experiment. The significance of the results suggests digital natives in the Computer Graphics Technology department at Purdue University may learn more efficiently from visual or possibly multimodal presentation of information. Further study is recommended utilizing similar testing environments with other subject groups such as non-natives to determine additional significance.

The literature regarding digital natives and narrative imagery suggested that this subject pool would display a difference in instructional efficiency between version A and version B of the training material. While this was in fact the case presented in this study, the possible learning style connection to this difference has not been determined here. While the high variability in the VARK results for the sample size in the study may have prevented a significant finding for this connection, the trend toward multimodal preference suggests that it may be a combination of learning styles among digital natives rather than a strictly visual preference that has resulted in the apparent instructional efficiency differences.

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APPENDICES

Appendix A.

Experimentation Instructions

Step One: Take the VARK questionnaire.

Go to <http://www.vark-learn.com/english/page.asp?p=questionnaire>

Follow the instructions and fill out the questionnaire. Click OK at the bottom of the page when you are done.
Record the numbers presented to you on the results page here:

Visual: _____ Aural: _____
Read/Write: _____ Kinesthetic: _____

Step Two: Use the Digital Natives training/testing module.

Go to <http://www.digitalnatives411.com/testing/>

Read the instructions, then select the button labeled "**TEST A / B**".

Enter User ID: _____, then press Submit and proceed through the training material and testing module, following the onscreen instructions. When you have completed answering the questions in the testing module and reach the "Finished" screen that thanks you for your participation, you may close your browser and move on to the survey questions below.

Step Three: Answer the survey questions below.

Gender: M / F Year of birth: _____

For the purposes of the following questions, "technological devices" refers to a range of digital devices including computers, video game systems, PDAs, cellphones (for purposes other than phone calls), etc.

-On average, how regularly do you utilize technological devices? (Circle one.)

Rarely Once a week Once a day Several times a day

-At what point in your life did you first begin using technological devices (for education, entertainment, communication, or other reasons)? (Circle one.)

Early childhood Adolescence Adulthood Today was the first day

-How would you rate your confidence level when using the technological devices you utilize regularly? (Circle one.)

"I can barely turn it on" "I can get it to do what I need" "I am a techno-pro"

These questions relate to your experiences during today's study.

-How do you feel about your educational experience with the training material you just utilized during this study? (Circle one option in each pair of choices.)

Boring OR Interesting Easy to understand OR Difficult to understand Comfortable OR Uncomfortable

-Would you enjoy learning about more topics using a training tool like the one you used today? (Circle one.)

Yes / No

Appendix B.

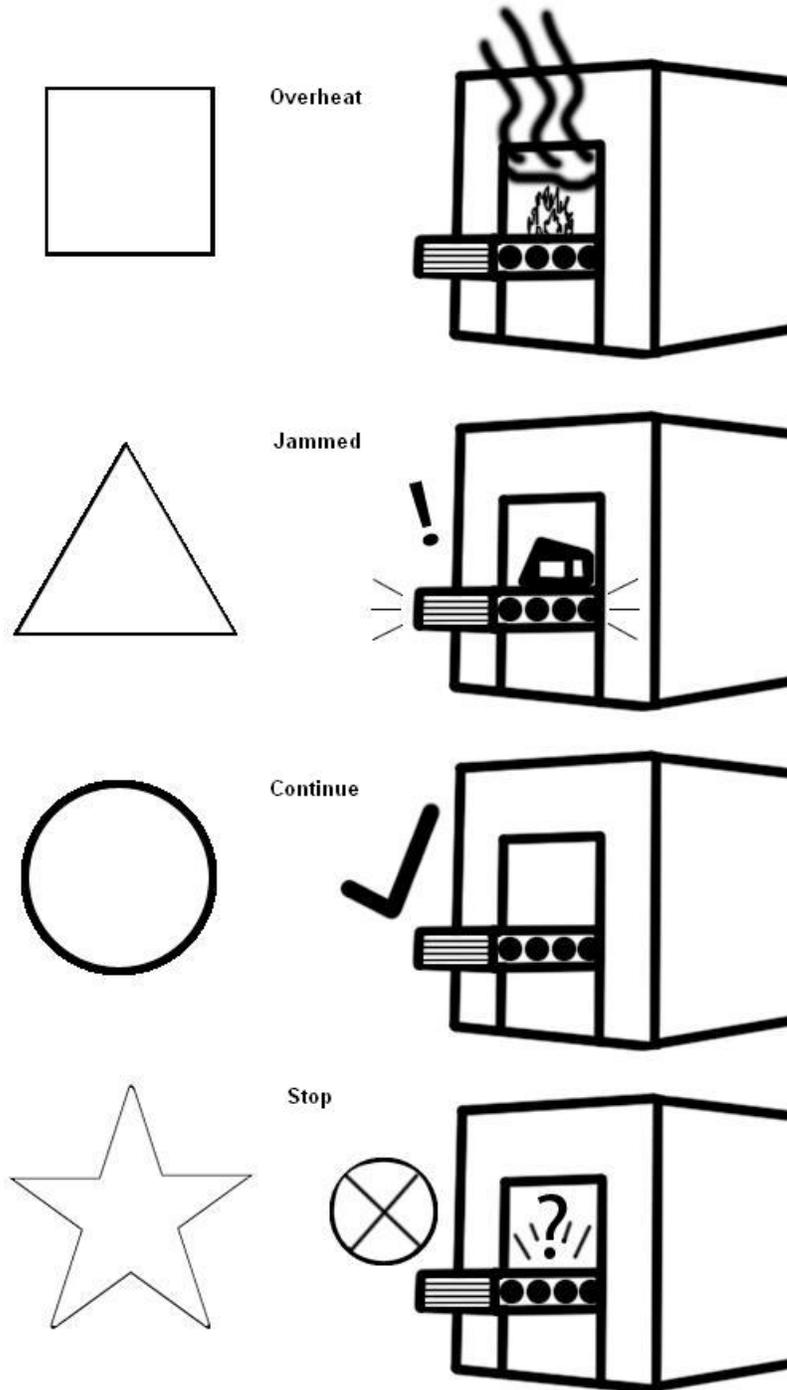


Figure B-1. Narrative images and associated symbols used in experimentation.

Appendix C.

Table C-1

Subject training time and test accuracy.

User ID	Version	Overheat	Jammed	Continue	Stop	Training Total	Test Accuracy
2	B	17	9.97	6.88	6.44	40.29	3
3	A	77.57	9.52	9.91	16.35	113.35	4
4	B	27.13	5.77	43.68	7.41	83.99	4
5	A	46.58	29.83	30.86	26.05	133.32	4
6	B	16.71	12.39	8.48	11.23	48.81	4
8	B	24.62	13.31	4.19	8.53	50.65	4
10	B	82.39	7	26.64	0	116.03	2
11	A	89.51	13.5	26.77	15.32	145.1	4
12	B	25.26	3.9	43.3	13.27	85.73	4
13	A	136.05	22.5	27.41	11.03	196.99	4
14	B	43.64	7.26	35.12	11.14	97.16	2
15	A	17.68	16.24	19	58.03	110.95	4
16	B	29.6	8.53	20.99	0	59.12	2
17	A	17	5.3	2.39	8.77	33.46	4
19	A	58.29	36.69	56.14	55.74	206.86	4
20	B	34.02	26.22	7.78	28.5	96.52	4
21	A	60.04	16.3	13.98	58.5	148.82	4
25	A	30.22	3.62	40.93	29.18	103.95	2
28	B	20.24	7.19	9.61	5.89	42.93	2
29	A	17.92	8.89	8.31	67.26	102.38	4
30	B	71.19	24.05	52.62	12.33	160.19	4
31	A	24.27	4.06	9.69	9.54	47.56	4
34	B	9.5	6.58	3.6	6.51	26.19	4
36	B	68.47	58.32	0	47.17	173.96	1
37	A	23.27	6.65	14.51	77.86	122.29	1
38	B	22.72	9.57	28.13	4.88	65.3	4
43	A	48.32	17.27	10.88	26.57	103.04	4
44	B	13.82	11.63	6.44	3.77	35.66	4

Table C-2

VARK results and subject demographics.

User ID	V	A	R	K	Gender	Year of Birth
2	6	7	6	10	M	1990
3	13	7	6	15	M	1992
4	6	8	7	9	M	1991
5	5	8	9	8	F	1991
6	14	4	13	8	M	1988
8	10	7	7	4	M	1991
10	4	5	4	4	M	1989
11	7	10	8	12	M	1989
12	12	8	11	12	M	1992
13	10	11	6	14	M	1990
14	11	9	5	13	M	1989
15	11	1	6	4	F	1990
16	10	12	14	10	M	1992
17	10	9	5	13	M	1990
19	6	10	6	8	F	1992
20	9	7	13	12	F	1984
21	10	7	4	12	M	1990
25	15	6	4	11	M	1991
28	6	9	7	8	M	1991
29	5	3	2	6	M	1989
30	2	2	2	10	M	1991
31	8	4	3	11	M	1990
34	9	12	11	10	M	1992
36	11	8	7	13	M	1986
37	9	7	6	12	M	1988
38	3	2	2	9	M	1992
43	7	14	4	10	M	1992
44	12	6	11	10	M	1991