

Usage of a Web-Based Factorial Experiment Testing System (FETS)

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Abstract

This paper describes the Factorial Experiment Testing System (FETS), a system to create, deploy, and analyze factorial experiments involving human subjects using innovative web technologies. Factorial experiments involve multiple factors that are tested and compared simultaneously in study groups. They allow for more complex questions to be asked and for those questions to be answered using a smaller experiment set and testing pool than would otherwise be needed. By using the latest web browser technologies, such as Asynchronous JavaScript and XML (AJAX), and dynamic web content delivery using Apache, Perl and MySQL, the system is able to quickly and interactively design, deliver, and manage complex factorial experiments with any of today's popular web browsers.

1. Introduction

Conducting a simple factorial experiment with a small data set is fairly easy to do. However, results from such an experiment typically do not produce a statistically valid answer to a question. To ensure a valid answer, a large data set is often needed, even for a small experiment. For a more complex experiment, an even greater sample size is needed. Conducting experiments of this nature when dealing with human subjects is complex, cumbersome, and difficult to distribute to participating subjects from different areas of the country or world. To do that, a system that can electronically deliver experiments to subjects and collect their data is needed. This paper describes using a solution to this problem involving a web-based application. The latest in web technologies have been used to visually enhance and increase the speed of this application when compared to many other web applications in use today.

2. User Management

All users, whether subjects to partake in an experiment or facilitators who are creating their own experiments, must first register with the system. When registering, a simple form is displayed to the user. This form asks for the normal, basic information required to interact with users of the system. A requirement of the system is that a unique e-mail address be used for each user, since it will be used as that user's login identifier.

This form does several dynamic checks and can report errors as they occur. These checks include making sure the user has filled in all the fields and that the password they have selected is not too short. These checks are all performed when the user clicks on the "Send Request" button. If there are errors, a text message describing the problem appears in red near the bottom of the form. Also, any fields that contain errors are highlighted in red, helping the user to quickly identify and fix any problems. Finally, a check is run automatically in the background when the user has filled in their e-mail address. This check makes sure that the e-mail address they have entered looks like an e-mail address and that the user does not currently exist in the system. In Figure 1 below, an example where a user has entered a short password is shown. All other fields, including the e-mail address, which shows the word "Passed" in green, have passed their sanity checks.

First Name:	<input type="text" value="John"/>
Last Name:	<input type="text" value="Smith"/>
Password:	<input type="password" value="****"/>
Password (again):	<input type="password" value="****"/>
E-mail:	<input type="text" value="johnsmith@joescollege.edu"/> Passed
* Please use an address associated with your institution. Anonymous addresses such Google, Yahoo, or Hotmail will not be approved in general.	
Institution:	<input type="text" value="Joe's College"/>
The passwords you provided are too short (6 character minium).	
<input type="button" value="Send Request"/> <input type="button" value="Clear"/>	

Figure 1 - Registration Form with Errors

When a user successfully completes registration, their request is placed into the registration table and an e-mail message is sent to the e-mail address they provided. This message contains a welcome message along with a URL that the user must access within 24 hours of making a registration request; otherwise, the request is deleted. This simple check makes sure that anybody who registers with the system has provided a valid e-mail address and that the address does indeed belong to them.

After the user has successfully created their account, they must log in. The login box also contains code to check the validity and existence of the provided e-mail address. Similar to registration, if there is an error, a descriptive message is shown to the user and they are not allowed to continue until the error is fixed. In Figure 2 below, an attempt to log in where the user did not enter in their e-mail address correctly is shown. It is obvious that the user is missing a period from their address and the error message reflects the fact that the e-mail address looks like it was not entered properly.

E-mail:	<input type="text" value="johnsmith@joescollegeedu"/>
Password:	<input type="password"/>
E-mail address looks invalid.	
<input type="button" value="Login"/> <input type="button" value="Cancel"/>	
Forgot your password?	

Figure 2 - Login with Invalid E-mail Address

3. Subjects / Students

In this section, the system is explored from a subject or student's perspective. First, users must register for an experiment. After they have registered, they may start the

experiment. If any problems should occur, or if requested by the experiment, they can leave the experiment or the entire system and come back at a later time.

3.2. Registering for an Experiment

When dealing with large numbers of students or subjects, the typical solution is to generate a subject list in some application, usually Microsoft Excel™. The list is then exported from Excel in some format and imported into the application that needs the list. Inevitably, subjects will be added or removed from an experiment, making the list out of date and requiring some sort of update to occur. The FETS system does not use a student list. Instead, a 'secret code' is used to access an experiment. When a user logs into the system, they are shown a link that will allow them to register for any experiment. When clicked, a dialog box is shown for them to enter in an experiment's secret code (Figure 3 below). If the code is valid, the subject is assigned to the correlating experiment and is immediately allowed to view the experiment.

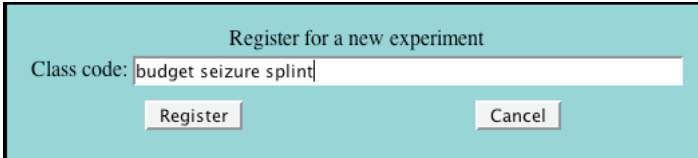


Figure 3 – Student Experiment Registration

Secret codes by default are three random, lower case words from an English dictionary, with no word shorter than five characters or longer than eight characters.

Once a user has successfully registered for an experiment, they most likely will continue with the experiment by clicking on the "Start Experiment" link (Figure 4 below).

Contact Experiment Facilitator'. Below this item is a link '[Start Experiment](#)'." data-bbox="282 641 716 720"/>

Figure 4 - Student Experiment List

If any problems should occur, they have the option of contacting the experiment facilitator. By default, any contact with the facilitator is anonymous, for IRB (Institutional Review Board) purposes. However, if the student requires a response, they can elect to send contact information to the facilitator. This form allows contact to merely be initiated. The system does not track or store messages for either the subject or the facilitator.

3.3. Participating in an Experiment

When a user is participating in an experiment, the screen is split into two sections. The top section (Figure 5 below) provides the student with information on the current experiment, which content they are currently looking at, and if timed, how much time they have left to view the current content. Subjects can also skip the current content page or cancel out of the experiment using the links provided in this section.



Figure 5 - Upper Content Section of a Timed Content Page

If the content is timed, the text for the timer turns to red when 10 seconds or less is available. When the time runs out, the system moves the user to the next content page. If the currently displayed content is a survey or quiz, the system also submits the user's answers, regardless of whether or not they have completed the survey.

The lower section of the subject's experiment page displays content. There are currently two types of content: Lesson Pages and Surveys. Lesson Pages contain simple HTML, which can contain links to images, audio, movies, tables or anything else that can be viewed in a browser. Surveys contain a set list of questions the facilitator wishes the subject to answer. There are three types of questions: Short Answer, Essay, and Multiple-choice. Short Answer questions display a small text box for the user to enter in their response and Essay questions display a larger text box. Multiple-choice questions display any number of options from which the student must select a single answer. Questions are displayed in a table, with alternating colored backgrounds to help the user determine which options belong to which question. In Figure 6 below, an example of each of the three types of questions is shown. First a multiple choice question with five options, then a short answer question, and finally, an essay question.

What is your Biology skill level (1=Low, 5=high)?	<input type="radio"/> 1 (Low) <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input type="radio"/> 5 (High)
What is your age?	<input type="text"/>
Describe your educational background:	<input type="text"/>

Figure 6 - Example Survey Questions

Questions can be displayed in random order and multiple-choice questions can have their options displayed randomly as well. Regardless of how a question is displayed, all answers are recorded in such a way that the facilitator can easily analyze them. When a student answers a question, their student id, the question id, and the question option id are all recorded. Thus, the order in which they are displayed has no negative effect on the facilitators ability to analyze the subject responses.

Many studies include questions with a scale, from 1 to 100, asking the subject for their confidence level in a particular answer they have provided. Unfortunately, HTML forms do not have a slider or scale input element. For FETS, a new slider user interface element, as shown in Figure 7 below, was created to gather this data.

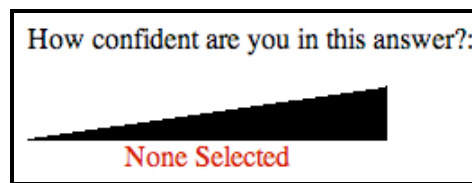


Figure 7 - Confidence Level Input with No Selection

Interacting with the confidence level element only requires a single click. The user moves their mouse along the scale and clicks at the appropriate spot. A red line displays their current position in the scale and feedback text, such as "Very Low" or "Somewhat High" is displayed above the scale. When the user makes a selection by clicking, the text element of their selection is displayed below the scale (Figure 8 below).

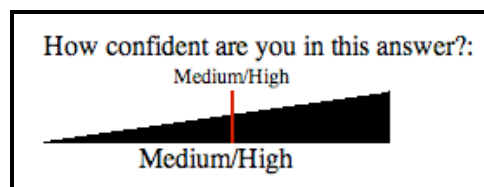


Figure 8 - Confidence Level Input with a Selection

Although much of this element has been specifically tailored for the FETS system, it is important to note that internally, it sets and modifies an HTML INPUT form element. This feature means that although JavaScript and mouse events are used to display a fancy scale, whatever data is being generated by the element can be accessed using the same object reference calls that would be used to access any other HTML INPUT form element in the DOM. Thus, processing any user survey is straightforward, regardless of whether or not the survey contains any confidence level elements.

Anytime the user takes any action, whether logging in, registering for experiment, or even submitting a survey, an entry is recorded in the database recording the time, student id, experiment track number, if available, and a short message describing the action the

user took. These messages also describe the last content page the user was shown and is used to continue an experiment when the student either has a problem, such as a browser or network crash, or when they are asked to complete some other task before continuing with the experiment.

In all, a simple, robust, and useful interface for students to interact with the FETS system has been created.

4. Facilitators

In comparison, the facilitators interface is more complex than the subject's interface. Once logged in, the facilitator is presented with two options and a legend as shown below in Figure 9. First, they may create a new experiment and secondly, they may modify an existing experiment. The legend, displayed on the right-hand side of the screen, helps the facilitator to identify the possible actions available throughout the system. On the left-hand side of the screen, are special links, noted by the "Click to edit / expand" icon. In this example, the second experiment, "VCell SubTitles," has been clicked on and the current options available with this experiment are displayed to the user.



Figure 9 - Facilitators Starting Page

Experiments can be edited, copied, deleted, renamed, and locked. Most of these options are straightforward, but there are some facts to note. First, copied experiments copy only layout and content, subject data is not copied and neither are the experiment's secret keys, which must be unique within the system. Secondly, an experiment must be locked in order for subjects to be able to access it. When locked, a facilitator cannot modify the experiment until unlocked. Usually, a facilitator will wish to edit their experiment. Once an experiment is selected for editing, the facilitator will be presented with five new sections: the current experiment title, Experiment Options, Content Items, Questions, and Treatment Tracks (Figure 10 below).

Experiment: VCell SubTitles 1									
Experiment Options:	Secrets	Assignment Type: Random Serial	Subject: Biology						
<table border="1"> <thead> <tr> <th>Content Items</th> <th>Questions</th> <th>Treatment Tracks</th> </tr> </thead> <tbody> <tr> <td> Create New Content Item Lesson Pages: <ul style="list-style-type: none"> Animation with both Animation with narration Animation with subtitles IRB Notice Surveys: <ul style="list-style-type: none"> Post-Treatment Pre-Treatment Survey </td> <td> Create New Question Click for options: <ul style="list-style-type: none"> Age Biology Skills chain elongation Colleg Course Count Computer Skills Gender protein synthesis sequence Ribosome shift tRNA initiation binds to </td> <td> Create New Treatment Track Click for options: <ul style="list-style-type: none"> Narr/Subt -> Text Narration -> Text Subtitles -> Text Text -> Narr/Subt Text -> Narration Text -> Subtitles Display All Track Content Items </td> </tr> </tbody> </table>				Content Items	Questions	Treatment Tracks	Create New Content Item Lesson Pages: <ul style="list-style-type: none"> Animation with both Animation with narration Animation with subtitles IRB Notice Surveys: <ul style="list-style-type: none"> Post-Treatment Pre-Treatment Survey 	Create New Question Click for options: <ul style="list-style-type: none"> Age Biology Skills chain elongation Colleg Course Count Computer Skills Gender protein synthesis sequence Ribosome shift tRNA initiation binds to 	Create New Treatment Track Click for options: <ul style="list-style-type: none"> Narr/Subt -> Text Narration -> Text Subtitles -> Text Text -> Narr/Subt Text -> Narration Text -> Subtitles Display All Track Content Items
Content Items	Questions	Treatment Tracks							
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Figure 10 - Facilitators Edit Experiment Sections

The experiment title is displayed prominently so that the facilitator knows which of their experiments they are currently editing. The Experiment Options section allows the facilitator to edit the experiment's secret codes, the way in which students are assigned to a treatment track, and the general subject area for this experiment. The following three areas allow the facilitator to describe the actual content that will be presented to the subject and design their factorial experiment. Content is classified as either a Lesson Page or a Survey. Lesson pages contain HTML and Surveys contain Questions. Content is then organized into Treatment Tracks.

4.2. Experiment Manipulation

Throughout the interface is a simple pop-up menu, usually activated when the facilitator clicks on a link, which can be seen in Figure 9 above. These menus differ depending on the item, but typically allow an item to be edited, deleted, or renamed. A "Close" button is always present in these menus.

Experiments have secret codes associated with them as an access control mechanism. Secret codes also allow a facilitator to virtually partition the subject space. For example, an experiment facilitator may have three sections of a class, all of which they wish to participate in an experiment. Instead of giving all three sections the same secret code, they may generate and give each section a different code. Within the system, all of the subjects are treated the same. However, when the facilitator requests usage reports, they may include or exclude any section they wish in the results by modifying which secret codes are used to generate such reports. By using this mechanism, not only can a specific subset of groups be examined, but such groups can also be compared and contrasted

Facilitators are asked to select a general subject area for their experiment, such as Biology or Psychology. Currently, the experiment subject is just displayed to the user, as "General" is seen in Figure 4 above. It is hoped that in the future, a set of experiments for many of the topic areas will be created and either allow anyone in the public to partake in any open experiment or allow for facilitators to assign a set of experiments in a certain topic area to their subjects. This functionality would also promote a sharing

system, where a facilitator could assign an experiment from another facilitator to their students, in the hopes that the other facilitator would reciprocate, thus increasing the sample size of each experiment to obtain results that are more accurate.

Once the basics of the experiment are set up, the facilitator then creates content within the system. The first type of content, a Lesson Page, is the simplest with which to work. When edited, the lower portion of the screen displays an input text editing area and a preview area side-by-side, as shown below in Figure 11. As the user enters data into the text editing area, the preview area is automatically updated. In some cases, the user may wish to increase the screen area available to edit a Lesson Page. In this case, they may click on the "Open Window" link, which will expand the text editing area to the width of the screen and open a separate window showing the live preview.

The screenshot shows a web-based content editing interface. At the top, it says "Content Name: **IRB Notice**" with "Save Changes" and "Cancel" buttons. Below this are two main sections: "Edit" and "Preview - Open Window".

The "Edit" section contains a text area with the following text:

North Dakota State University supports the practice of protecting research participants' rights. Accordingly, this project was reviewed and approved by the NDSU Institutional Review Board. The information in this consent form is provided so that you can decide whether you wish to participate in our study. It is important that you understand that your participation is considered voluntary. This means that even if you agree to participate you are free to withdraw from the experiment at any time, without penalty.

<P>

This system allows for testing various instructional methods. Your experiences will differ from those of your colleagues. Some exercises are timed, some are not.

<P>

This experiment poses no known risks to your health and your name will not be associated with the findings. Upon completion of your participation in this study you will be provided with a brief explanation of the question this study addresses. If you have any questions not addressed by this consent form, please do not hesitate to ask.

<P>

We thank you for your time.

<P>

The "Preview - Open Window" section shows the rendered version of the text, with paragraph breaks and bold formatting for "IRB Notice".

Figure 11 - Facilitator's Content Editing Form

Using this simple form and the fact that content can be timed, some very creative ways of presenting information can be accomplished. For example, one could create a series of content pages, each containing a single image, and present them like a slideshow.

The other type of content, Surveys, requires interacting with not only the Content Items control area, but also the Questions control area. Surveys can be created with no questions in them initially, but eventually, the facilitator will want to add questions to them. Of the three types of questions that can be created, the most complex is the multiple-choice question. When edited, a dialog with a table and various form elements is shown that allows a facilitator to enter in the question along with any number of options (Figure 12 below).

Question Name: **Insomniac**

Question text: Do you have trouble sleeping at night?

Add a new option to this question

	Option	Move Up/Down	Remove
1	Yes	↑↓	✗
2	No	↑↓	✗

Save Cancel

Figure 12 - Facilitator's Question Edit Dialog

Once several questions have been entered into the system, they can be added to a survey. Each question can appear in a particular survey only once; however, a question can be placed in as many surveys as desired. Survey manipulation is done with the Survey editor, which allows questions to be added, removed, and re-ordered within a survey (Figure 13 below).

Content Name: **Pre-Treatment**

Randomize presentation of questions in survey? **No**

Add a question to this survey

	Name	Randomize Options	Ask Confidence	Move	Delete
1	tRNA initiation binds to	Yes	Yes	↑↓	✗
2	Ribosome shift	Yes	Yes	↑↓	✗
3	protein synthesis sequence	Yes	Yes	↑↓	✗
4	chain elongation	No	Yes	↑↓	✗

Save Cancel

Figure 13 - Facilitator's Survey Editing Dialog

There are also several options available when editing a survey that control how the survey is displayed to the user. As discussed earlier, the order of the questions and options for multiple choice questions can be randomized. Another option allows the facilitator to include the confidence level input element along with the question (See section 3.3 above, specifically Figure 8). These options are 'toggle' options. The background color of the options reflects the current option value, giving additional feedback concerning what options are being applied to a particular set of questions.

Besides the Question and Survey editing dialogs, there are several other dialogs in the system that use a table to display information to the user. In all of these tables, there is some way to add, remove, and reorder rows. In almost all cases, this manipulation is done using the DOM and changes appear to the user nearly instantaneously. Communication is only done with the server when the user has completed all changes and clicks on whatever 'Save' or 'OK' button is displayed.

The final editing area involves Treatment Tracks. When Treatment Tracks are edited, a dialog as shown in Figure 14 below is displayed, allowing content to be added, removed, sorted, and to have a time associated with a specific piece of content.

Track: Narr/Subt -> Text

Add Content Item to this track

	Content Name	Display Time seconds	Move Up/Down	Remove
1	IRB Notice	0		
2	Survey	0		
3	Pre-Treatment	0		
4	Animation with both	30		
5	Text of Narration	0		
6	Post-Treatment	<input style="width: 40px;" type="text" value="0"/>		

Figure 14 - Facilitator's Track Editing Dialog

First, content can be added to the track by clicking on the "Add Content Item to this Track" link. When clicked, a sub-dialog box is shown with a list of any unused content items (Figure 15 below). A content item can only be included in a particular track once. When a new content item is selected, it automatically appears as the bottom row in the Track Editor.

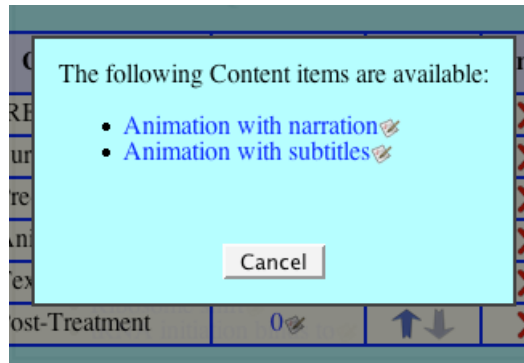


Figure 15 - Facilitator's Add Content to Track Sub-Dialog

Any content item can be time restricted. Content items with a time of zero are shown indefinitely and a "Continue" button is added to the bottom of the content. Any of these times can be editing in-place using the number editing element created for this system and is shown above in Figure 14 (bottom row). When a number is clicked on, it is replaced by a very small form allowing the facilitator to change its value.

Finally, there is delete row icon that, when clicked, displays a sub-dialog confirming the user wishes to remove that particular piece of content from the current track. When working with complex factorial experiments, keeping track of which content is in which treatment track can be difficult. To help with this problem, a simply summary of all the content contained within all of the tracks can be displayed. Contained in this summary is simply the track name and the names of the content contained within the track.

4.3. Data Analysis

Once an experiment has been designed and subjects have partaken in it, data analysis must be done to find results. Two approaches are taken to this analysis. First, a basic statistical summary of the results along with an ANOVA analysis is shown. Secondly, facilitators are able to extract out the data for their experiment in various formats so that they may further analyze the data in whatever means they wish.

The included statistical summary provides several important pieces of information to the facilitator. Of note is a list of names of the subjects that have completed the experiment. The list provided to the facilitator does not indicate how the student answered any questions, which content they viewed, or even the student's identification number. The subject report is simply the list of names of the subjects that have partaken in an experiment.

A simple statistical report for each survey in the current experiment is also provided. This report shows a breakdown of responses as a number, a percentage, and a horizontal bar graph (Figure 16 below).

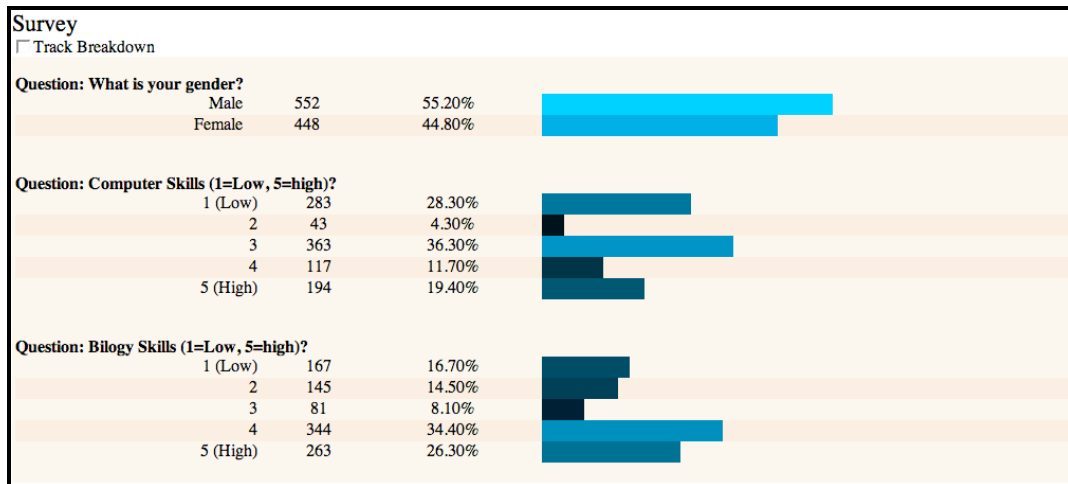


Figure 16 - Sample Statistical Report for a Survey

In addition to the above simple summary, an ANOVA summary and box plot (Figure 17 below) of the experiment's results is provided. Both of these analyses are generic and compare all of the questions asked during the pre-treatment and post-treatment surveys. Results can be limited to various sections by making use of the 'secret code' limiters, but results for a single question or an interaction between questions is not yet implemented.

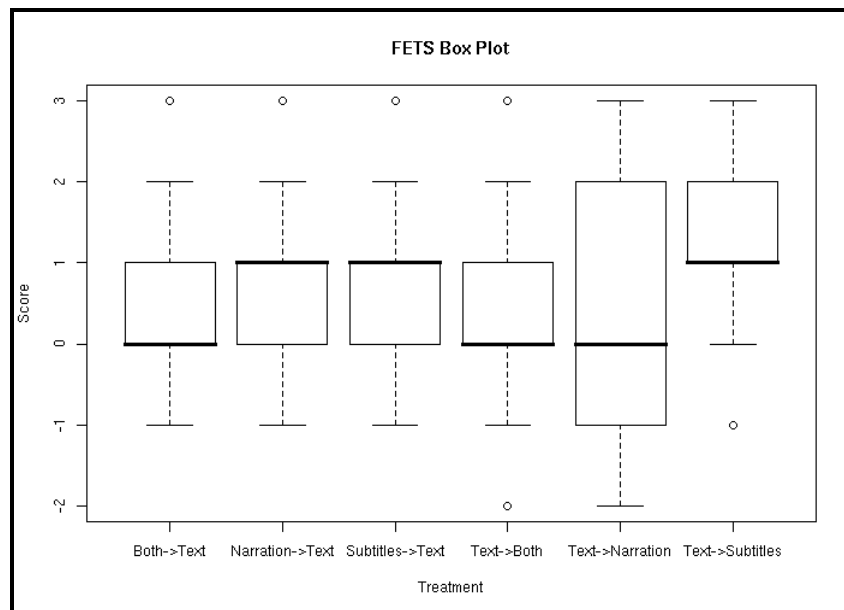


Figure 17 - Sample Experiment Results Box Plot

Not every type of analysis that every facilitator could possibly want can be provided. It is simply not feasible to do so. Thus, the FETS system has the capability of exporting all or part of the data from an experiment into a file that the facilitator can then use for whatever purpose they wish. Two export options are available, a standard plain-text

export, commonly known as a CSV or Comma Separated Value list. For flexibility, this file can be exported with tab separators instead of commas. The export can also be preformatted for the Microsoft Excel™ application. Many programs accept Excel files as input and it is commonly used to generate graphs or other reports. Included in this report is the 'secret code' the student used to sign up for the experiment, the student's numeric id which was generated by the system, the track the student is assigned to, and the question and answer for any data the student generated, including the confidence level if it was requested.

5. Conclusion

In conclusion, a robust system capable of conducting factorial experiments on a large scale has been developed and tested. There is no need for users to install any additional software in order to use the system; the web browser they currently use is sufficient. The latest in web technologies is used to provide a rich application experience within this web browser and does not suffer from many of the drawbacks previous web applications display. Experiment subjects use a simple and intuitive interface that can cope with different failures. Experiment facilitators can create as simple or as complex an experiment set as they wish to create and can easily control who has access to those experiments. The system uses many user interface elements that are either easy to use or very similar to other interface elements the user should already be familiar with.