Human Bandwidth

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ABSTRACT

This project examines the effects of including multimodal output in menu-based systems. In the course of the project, the principles of multimodal interaction were examined. Based on these principles, an experiment involving a user's ability to retrieve data from a scrolling menu-based system. The experiment was intended to determine if the addition of sound and/or motion would improve a user's ability to retrieve information in a timely and accurate manner. The experiment suggests that the addition of movement improved a user's ability to retrieve information, while the inclusion of sound had no significant benefit.

INTRODUCTION

In the last two decades, the ease of access to information has increased dramatically. The most significant agents in this increase of information availability are computers and the Internet. With this increased access comes the need for new methods of presenting information in a useful manner.

The reigning paradigm for the development of computer interfaces is one of design and testing. Very few guidelines exist for creating an interface. Designers tend to use a process known as the cognitive walkthrough, in which the designer tries to imagine what steps the user would have to go through in order to complete a certain task using the interface under design. Following the walkthrough, the designer creates design several prototypes and then exposes them to test audiences. While these approaches are useful in the general sense, they leave something to be desired when applied to specific domains.

It is the purpose of this study to examine the usefulness of multimodal principles —that is, the inclusion of elements that engage multiple senses—in designing menu-based systems.

LITERATURE REVIEW

Multimodal interaction is divided into two fields: Multimodal Input, and Multimodal Output. Multimodal Input is concerned with allowing a user to use more than one channel to express information to a computer system. Several journals and publications regularly include articles on the subject, particularly those publications that deal with issues related to the field of Human Computer Interaction. *The Proceedings of* *the International Conferences on Intelligent User Interfaces* and the *Communications of the ACM* are two significant publications reporting advances in multimodal interaction.

One of the most prolific contributors to these publications is Sharon Oviatt. In her articles, she addresses such varied subjects as disambiguation in multimodal systems [21], multimodal systems in mobile environments [22], when and where multimodal interactions take place [24], and the various assumptions people make when dealing with multimodal systems [18]. While Oviatt is one of the most prolific authors on the subject, she is not the only significant name. Richard A. Bolt's "Put-that-there" has been referenced by over 200 articles as of March 2, 2010. Fitzgerald, Firby, and Hannemann have examined the theory of distinguishing individual input events in multimodal environments [9], as has Michael Johnston [11]. Moran, Cheyer, Julia, Martin, and Park have also published on the subject [16].

Interactions with computer programs are somewhat differnent than interactions with human beings, in that communications are often unimodal in their feedback. In word processing, feedback is almost entirely routed through the visual channel. Computer scientists have identified and described what Bert Bongers and Gerrit C. van der Veer call Multimodal Interaction Space (MIS)[4]. Bongers and Van der Veer identify eight modalities. Each of the first four senses—sight, hearing, smell, and taste—accounts for an individual modality. The sense of touch, however, is divided into the three haptic modalities; the *tactile*, our skin's ability to detect contact and texture; the *kinaesthetic*, our ability to detect the placement of our muscles and limbs; and the ability to detect when the body is actually moving. Added to these seven modalities is the ability to detect ambient temperature.

These eight modalities allow for multiple modes of interaction. Human interaction modes are classified as symbolic (such as writing) iconic (such as gestures), and para-linguistic (such as body language) [4]. One of the major issues with human output modalities is that they are hard to define, and often overlap. In fact, most human communications are multimodal to one degree of another. Speech can be accompanied by body language, for example [25]. Bongers and van der Veer give the example of a gesture that is intended to be seen being also perceived by the haptic sense modalities when it extends to touch the receiver [4].

Computers have the potential to engage the user in overlapping modalities. Bongers and Van der Veer propose the concept of Protospace architecture to describe these multidimensional sensory interactions [4]. Protospace is a three-dimensional design metaphor with possible applications in Augmented Reality, the use of computer overlays to enhance a person's ability to interact with the real world [4]. Protospace uses several concurrently running programs to allow the user to model objects, manipulate sound and create real time videos using gestures, voice commands, and a laser pointer.

The study of multimodal interaction is not exactly a new field. In his 1956 paper "Adventures in Tactile Literacy," Frank A. Geldard examined the various sensory qualities of the skin, their interactions with each other, and how they shape the way we perceive the world around us [10].

The article opens with a very brief discussion of the roles of sight and sound in the human perception of the world. Geldard describes the visual and auditory channels as being oversaturated, constantly assaulted by stimuli. This discussion of the two most used senses closes by suggesting that other, less utilized sensory paths could be used to communicate data. Following this premise are several examples of theoretical methods of communications. The proposed methods included Morse code delivered as dots of salt on the tongue, points of heat applied to the forehead, or acid applied to the skin.

Geldard questioned how long it would take to transmit a simple message in International Morse Code using the proposed methods. He found that than in the case of salt applied to the tongue, it might take as long as half an hour to spell out "Now is the time for all good men to come to the aid of the party." It could take over an hour for heat applied to the forehead to transmit the same message, given an appropriate cooling source to prevent blistering. It would take the better part of a day to deliver the message using acid applied to the skin, given an appropriate way to neutralize the pH levels. Geldard concluded that none of these methods is efficient enough in regards to time to make an effective communication medium.

Geldard also considered the use of electric current and mechanical vibration to transmit information. The article points out that while electrical current is generally too painful to the recipient to be useful as a means of communication, the pads of the fingers are sufficiently desensitized that they may detect certain frequencies without undue suffering. The article references the unsuccessful project "Felix" at MIT, which performed studies into using alternating current applied to the skin as a method of communication. Ultimately, Geldard set electrostimulation aside as being too poorly researched for a judgment on its viability as a communications medium to be made.

The article moves on to a discussion of mechanical stimulation. Geldard points out that mechanical communication, in the form of contextual pokes and prods, is already greatly utilized in the transmission of simple messages. Geldard gives examples, ranging from a quick jab to warn of an approaching authority, to somewhat complex culturally defined messages, such as blowing on the hands to indicate sorrow at parting.

For more complex mechanical messages, the article indicates four different variables that could affect communication: the frequency of the mechanical stimulation, the magnitude of mechanical stimulation, the duration of the mechanical stimulation and the locus of stimulation.

Experiments into training the skin to distinguish frequency have proven largely unsuccessful. While the skin is capable of making distinctions at lower frequencies, 20-50 cps, at higher frequencies such distinctions are lost. Furthermore, even at the frequencies where the skin is suitably aware, changes in the force of the stimulation can alter the perception of rate stimulation.

The thought that using multiple sensory channels to convey information might be more effective overall than the use of a single modality is not without basis. In a study of sound and sight interactions, Kaat Alaerts et al., at the Research Center for Movement Control and Neuroplasticity in Belgium, reported the effects of multimodal stimuli in the brain [1].

In a preliminary study, ten subjects between 20 and 30 years of age were selected to be the subjects of the experiment. The subjects were shown a video of a hand slowly crushing a plastic bottle, and instructed to mimic the action in time with the video. While the subjects performed this task, a surface electromyogram recorded the actions of select muscles. The muscle activity patterns recorded were used to select which muscles and which parts of the brain to monitor during the main study.

For the main study, thirteen subjects were shown various video clips and instructed to keep their arms relaxed. Their ability to see their arms was restricted. The clips the subjects were shown all contained easily recognized gestures and accompanying sounds related to the gesture. Six variations on this theme were presented: one in which sound was absent, one in which the sound was presented without the visual stimulation, one in which the sound and video were synchronized, two in which the aural and visual stimuli were not matched, and one in which no visual or aural stimuli were presented. While the subjects were viewing the video clips, the contractions of the selected muscles were recorded.

Muscle responses from multimodal input in which the visual and auditory stimuli were matched were considerably greater than the responses generated by unimodal stimulation. However, when adding the sum of responses from each of the unimodal tests, it was found that they roughly equaled the responses from the matched multimodal test. The implications of this study are that our ability to perceive the world around us is multimodally-dependent and our senses interlinked.

Although there has been limited study of multimodal output systems, a great deal of work has been done with multimodal input systems in terms of military applications. A study by P. R. Cohen et al. [6], on behalf of the Department of Defense, describes the results of a study into the efficiency of plain GUI (Graphical User Interface) in creating military map overlays as compared to voice control or pen-and-paper analog multimodal interaction. While early simulation testing found that voice-only control provided a theoretical 2- to 3 -fold speed increase over a typing-based GUI, software and hardware constraints resulted in task completion times that were slower than those created by the typing-based interface. Far more successful were the tests run on the combination of the menu-driven ExInit software and the pen-and-voice QuickSet interface. This setup showed significant improvements over both voice-only and gesture-only input methods. Specifically, the study found that the multimodal interface produced 36% fewer errors in task performance, 35% fewer speech disfluencies or misinterpretations by the voice recognition software, 10% faster task performance and 23% fewer words required to complete a task. Overall, the study reported the multimodal system having an 8.7-fold increase in efficiency over the pure GUI techniques.

In "Assessing the Benefits of Multimodal Feedback on Dual-Task Performance under Demanding Conditions," Ju-Hwan Lee et al. [13] describe a number of experiments designed to test the effectiveness of multimodal feedback in circumstances where the user must perform multiple tasks under conditions where reactions times and attention are important, such as while driving. Two experiments are presented, in which the user must use a touch screen mobile device while negotiating traffic.

The first experiment examines the subject's performance when offered unimodal or multimodal stimulus from the touch screen. Eight college students with normal vision and hearing were selected to participate. The subjects were isolated and presented with a simulated driving situation. The subjects were instructed to avoid a randomly moving vehicle over a sustained period of time. At the same time, the subjects were required to complete tasks on a touchscreen mobile phone. Feedback from the touchscreen came in one of four forms; purely visual; audio and visual; tactile and visual; audio, tactile, and visual.

The success of the subjects was measured according to metrics; the time between the vehicle executing a change in position and the subject's completing a maneuver to avoid the vehicle; and the time it took the subjects to accurately complete the task on the mobile touchscreen phone. Subjects scored noticeably faster when multimodal output containing all three of stimuli was present, followed by situations where both visual and auditory feedback was given.

The second experiment examined whether the intensity of multimodal feedback would have an impact on performance. Fourteen university students were the subjects of this experiment. The basic setup of the second experiment was the same as in the first experiment, with the added element that multimodal feedback varied in both the number of signals it returned in each interaction and the intensity of the feedback signals. Four categories were established; weak single, weak double, strong single, and strong double.

Using the same performance metrics, it was determined that a strong signal offered significantly faster reaction times than a weak signal. It was found that multiple signals resulted in better performance on reaction times but worse performance at completing tasks on the mobile.

In 2002, James Larson published an article titled “Should You Build a Multimodal Interface for Your Website?” The article points out three questions that need to be answered in order to judge the appropriateness of multimodal input in web based applications [12]. These questions are: does the new input mode add value to the Web application; does the application leverage the strengths of the new mode and avoid its weaknesses; does the user have access to the required hardware and software required by the new mode? [12]

As a result of the kinds of research outlined above, a body of assumptions has been established. “Ten Myths of Multimodal Interaction” by Sharon Oviatt [18], discusses ten commonly held assumptions about interface design that are not necessarily correct.

The first assumption is that if a system provides a multimodal interface, then the users will interact in a multimodal fashion all the time. Oviatt references several studies that show that while users do in fact prefer to interact in a multimodal fashion over applicable domains, their interactions generally take the form of a mixture of multimodal and unimodal input. The way a user chooses to interact with a multimodal system is generally the result of the sort of task the system is being used for. For example, when dealing with a spatial domain, only 20% of the commands were issued multimodally.

The second assumption is that the dominant modes of interaction are speech and pointing. This assumption is based on the relative popularity of Bolt’s “put-that-there” method, wherein commands are issued verbally while the objects of the commands are selected by a pointer of some kind [3]. Oviatt points out that this is very little advanced from the point-and-click metaphor of the mouse pointer. Furthermore, the article points out that such selection techniques account for only 14% of vocal interactions, and that only a small minority of gestures are used for selection in the tested cases [19].

The third assumption is that multimodal commands will occur simultaneously. Experimental data demonstrate that a pen gesture will often precede a vocal command slightly, a trend that seems stronger in languages that are topic-centered (similar to Chinese) than those that are subject-centered (as in English) [15].

The fourth assumption is that in systems where speech is included, it will be the dominant form of interaction. Experimental data indicates that speech is generally used to supplement gestures, particularly when dealing with spatial data [15][20]

The fifth assumption is that the language used when dealing with a multimodal system is the same as the language used when interacting with a unimodal system. The article demonstrates that the syntax of a command given unimodally is often more complicated and less fluent than the syntax of a command given multimodally. The article gives the example of a person indicating where to add a dock to a map of a lake. In the unimodal voice control, the command is given "Place a boat dock on the east, no, west end of Reward Lake." In the multimodal system, the command is given [draws rectangle] "Add dock."

The sixth assumption is that multimodal commands are redundant across modes. The example of the lake and the dock also works to disprove this notion. In addition, the article examines interactions of the Quickset architecture, where gestures store location data and vocal commands provide subject and action [7].

The seventh assumption is that error is cumulative across modes. Experimental data shows that a properly constructed architecture can compare information gained from more than one input style to catch and repair errors. An example of a misheard vocal command being corrected against a gesture command is given.

The eighth assumption is that all users will integrate input modes the same way. An experiment showed that four users out of a test group integrated their commands simultaneously while the remaining seven users integrated their commands sequentially.

The ninth assumption is that all input modes can carry the same data. This assumption fails to recognize that each mode carries information in a vastly different way. Even similar modes, the examples of speech and writing are given, carry different information. In the example given, the writing proves far more effective for describing spatial relations than the speaking.

The final false assumption is that the primary goal of multimodal interaction is efficiency, measured in the time it takes to complete a task. While studies have shown that the combined speech-and-pen metaphor can complete spatial tasks 10% faster than a speech-alone metaphor [15], other areas showed far greater improvement. Speech accuracy showed a 36-50% improvement in the speech-and-pen metaphor over the speech-alone metaphor. Oviatt concludes by stating that the future of multimodal interaction lies in blending modes of interaction, rather than in redundancy of communication.

Therefore, a framework for designing multimodal systems is needed. " Multimodal Output Specification / Simulation Platform," by Cyril Rousseau et al. [26] explores some of the concerns when developing a multimodal output architecture.

After a brief introduction in which it hints at some of the implications of ubiquitous computing, the article moves into the program development life cycles of a multimodal architecture. The article suggests the addition of a simulation step, before the prototype phase, in which the program is tested by the developer without the need for an end user. Three stages of simulation are identified; analysis, specification, and simulation.

The analysis stage is defined by three tasks. The first is to collect a body of data pertaining to the intended design. Next, an Interaction Context is constructed, based on the possible models and criteria for the project. After that, the Interaction Components, consisting of the media, modes, and modalities to be used are identified. Next, the information which is intended to reach to user, or semantic information, is compiled into the Information Units that the Interaction Components are intended to express.

Once the analysis is complete, the output specification stage begins. The first stage of specification is to formally define the exact relationship between the three data sets generated from the body of data. Exactly which modes will carry which semantic content must be established and fit into the best models. Once the formalized definitions are complete, the three data sets can be formed into a Behavioral Model, which suggests how to implement formalized relations.

With specification complete, the simulation stage follows. First, the semantic information undergoes a process call "semantic fission," where it is broken down into the individual data units that are going to be expressed in the simulation. Once identified, each individual data unit is associated with the modalities best suited to deliver it. Once the association is made, exactly how the data units are to be expressed is determined. Finally, the data units must be coordinated into an effective simulation of what the interface is ultimately intended to be.

It is therefore apparent that multimodal design principles can be used to enhance user interfaces. The above experiments and studies all indicate that including multimodal elements can enhance a user's ability to input data and can be used to reinforce a user's decision-making abilities. However, this leads to the question of whether multimodal principles can be applied to enhance a user's ability to retrieve data. This study is intended to discover whether the addition to multimodal elements will enhance a user's ability to retrieve information from a menu-based system.

EXPERIMENTAL PROCEDURE

Resources

- Adobe Flash CS4 Professional
  - Adobe Flash CS4 Professional was used to design and script the menu systems
- PHP
  - The website the survey was hosted on was scripted in PHP.

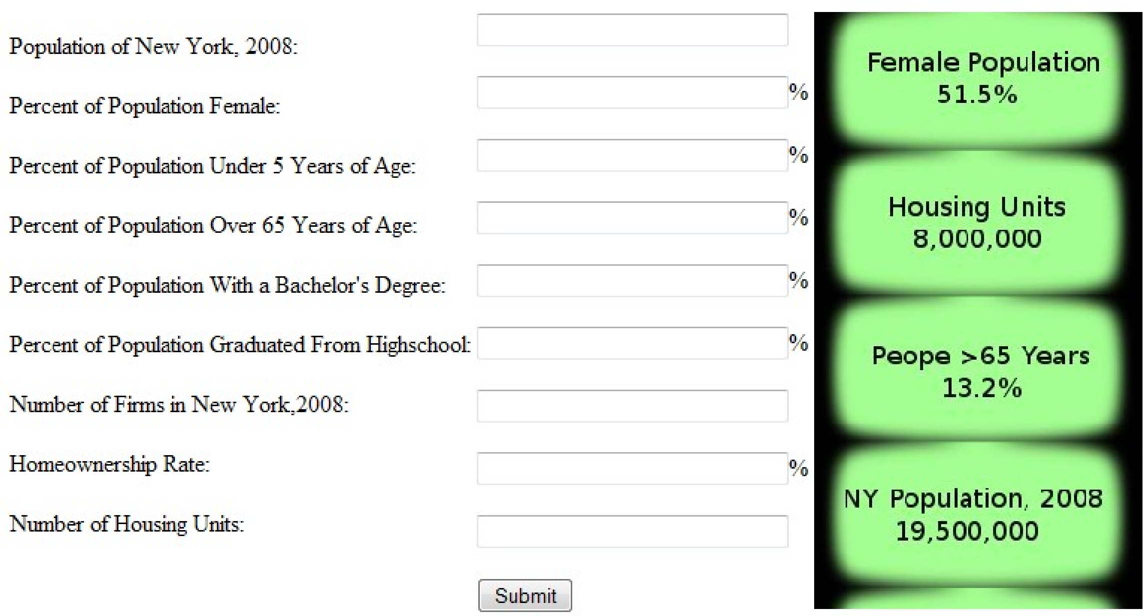
– http://muzziqp.co.cc/

– The survey itself can be found at this web address.

Methodology

The hypothesis upon which this experiment is predicated is that a multimodal framework containing moving visual elements associated with audio cues can be used to enhance a user's ability to retrieve information from a menu based system.

The user is presented with nine simple fill in the blank questions to answer. To the right of the questions is a scrollbar containing images in which the answers are written. The scrollbar is deliberately designed so that all nine answers can not be viewed at a single time, so to retrieve the answers to the questions, the user must scroll up and down to complete the questions. The answers are not given in the same order as the questions.



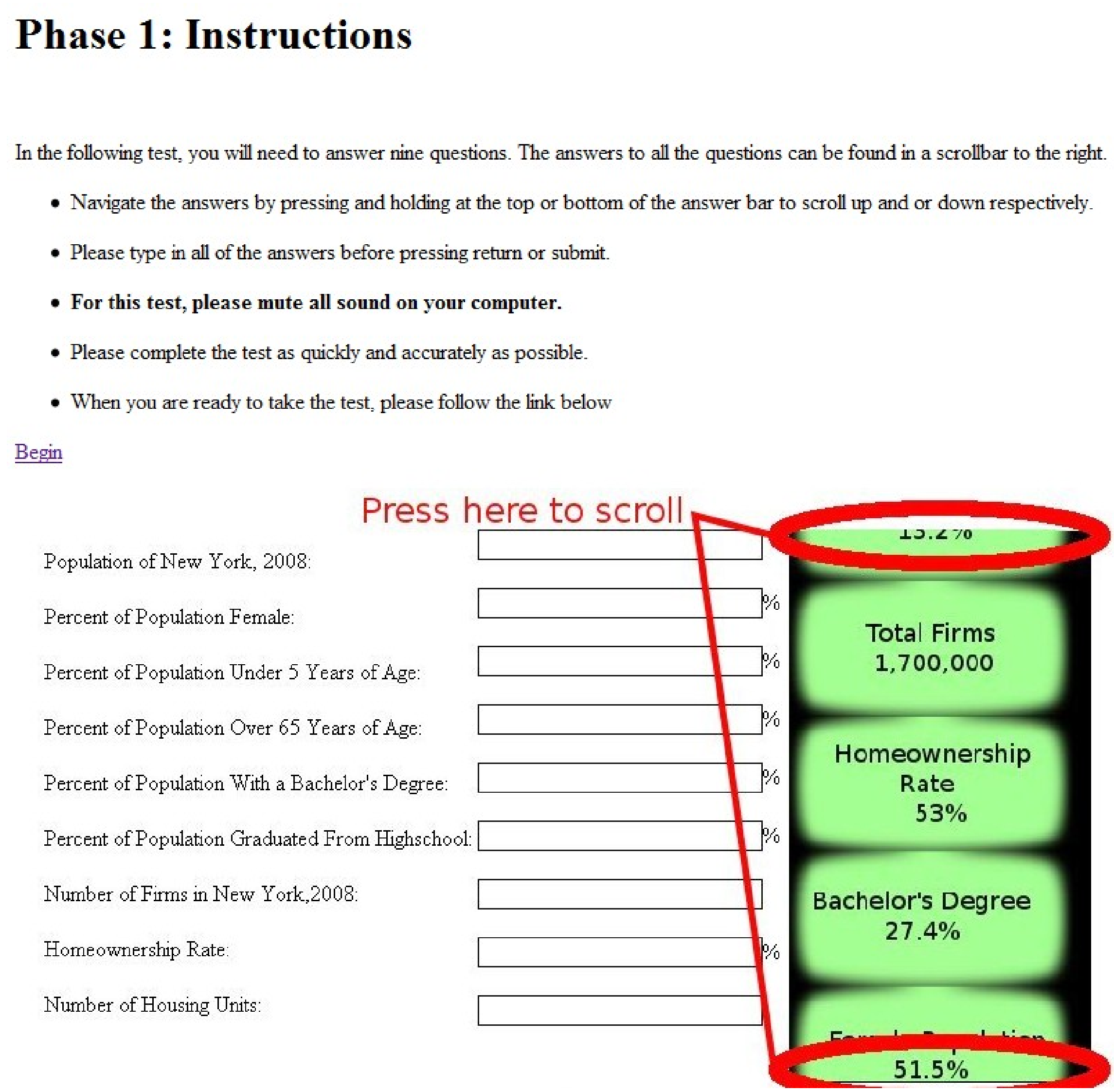
There are four variants of this design, which associate varying degrees of sound and motion with the selection of the correct answers.

In the control (C), the scrollbar is silent and static, requiring user interaction to scroll up and down.

The first variant (Sound) introduces sound to the design. Each of the answers becomes associated with a sound that plays whenever the mouse moves over the image it is presented on.

In the second variant (Motion), the scrollbar is not static. Instead, the images containing the answers constantly scroll by. The constant scrolling action may be overridden by the user with a simple click of the mouse on the scrollbar, and will pause for 2 seconds after every user interaction before resuming scrolling. This variant is silent. In the final variant (Sound+Motion), the scrollbar incorporates both sound and motion, both identical to the single-variable trials.

Before each test, the user is given instructions on how to navigate the interface:


Phase 1: Instructions

In the following test, you will need to answer nine questions. The answers to all the questions can be found in a scrollbar to the right.

- Navigate the answers by pressing and holding at the top or bottom of the answer bar to scroll up and or down respectively.
- Please type in all of the answers before pressing return or submit.
- **For this test, please mute all sound on your computer.**
- Please complete the test as quickly and accurately as possible.
- When you are ready to take the test, please follow the link below

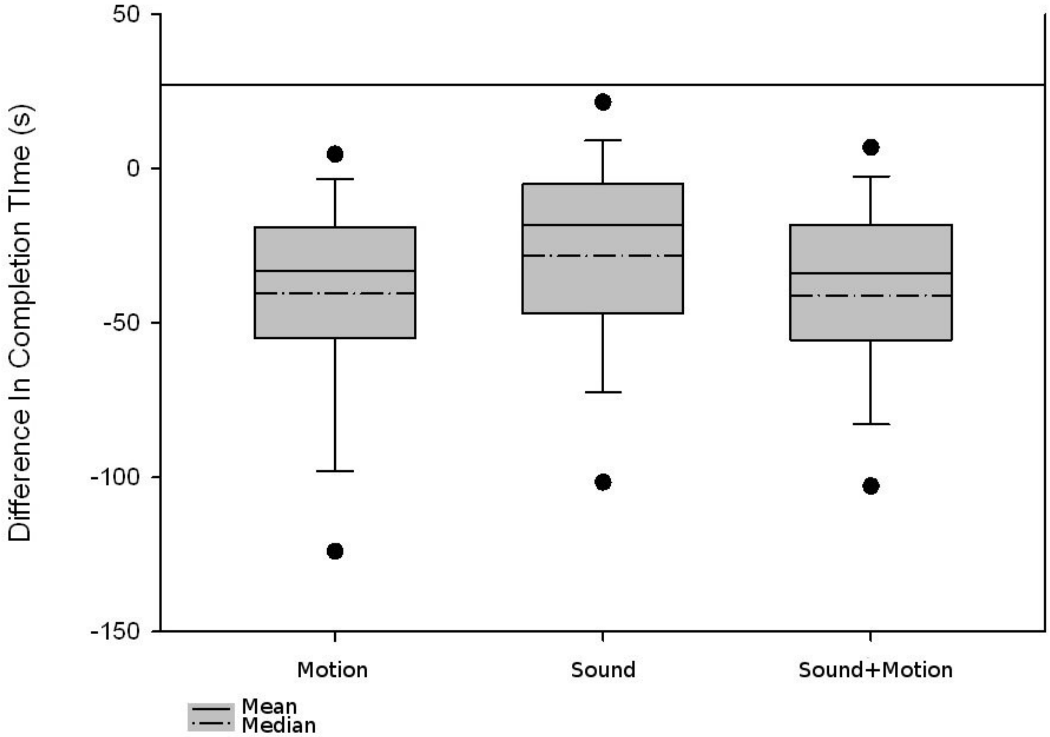
Begin

The user is first asked to complete the control. Once the control is completed, the user is asked to repeat the test. For the repetition, one of the three variants is assigned randomly. In all cases, the user's success is measured in the time it takes for them to complete the entire test, and the number of questions they completed correctly.

RESULTS

The survey was sent out on the WPI student mailing list. Three hundred fifty complete responses were received, one hundred eight having taken the sound variant (Sound), one hundred twenty one having taken the movement variant (Motion) and one hundred twenty one having taken the sound and movement variant (Sound+Motion).

The results of the variant including sound had a mean difference between the treatment and control of -28 seconds, with a standard deviation of 38.45 seconds. In the variation with movement as the treatment, the mean difference between treatment and control was -40 seconds with a standard deviation of 45 seconds. In the final variant, including both sound and movement in the treatment the mean time difference was -41 seconds with a standard deviation of 42 seconds. On average, in the tests that included motion the second trial was completed in roughly 63% the time of the control, while tests that included only sound were completed on average in 74% of the time of the control.



In addition, the Pearson product-moment coefficient for the overall experiment was calculated as .357, with Sound registering 0.42, Motion 0.26, and Sound+Motion 0.43, indicating in each case that there was observable and positive correlation between the tests.

It should be noted that no treatment had any appreciable affect on the accuracy.

DISCUSSION

The results of the experiment show that when an interface includes more facts or options than a user can see in a single frame, then the use of scrolling movement in displaying the information can improve the user's ability to identify desired information.

It should also be noted that the addition of sound to the experiment seemed to have no noticeable positive effect.

The results of the experiment show improvement in time between the control and the repeat for all treatments. Some of this improvement can be attributed to familiarity due to repetition. However, both the Motion and Sound+Motion trials were significantly faster than the Sound trial, indicating that the addition of movement to the scrollbar resulted in a significant improvement in the speed with which the user was able to complete the trial. Similarly, there was not a significant difference between the Motion and the Sound+Motion trials. This seems to strongly indicate that, in the absence of a strict control where the user takes the control twice, that sound had a minimal effect on the speed with which a user completed the trials. One subject even suggested that they found the sound distracting. Unfortunately, the lack of a strict control makes it impossible to make a definitive statement about the effects of the treatments, so we can only observe their effects relative to each other.

Another point of interest is the high coefficient of variability. In all three treatments, the standard deviation was greater than the mean. This degree of variability can be attributed not only to varying degrees of skill on the part of the users, but as a result of the test being taken on multiple platforms, including desktop PCs, laptop PCs and smartphones. A few users provided feedback, which the test did not request, identifying what platform they had taken the test on.

These results are contrary to the original hypothesis. In almost all cases identified in the literature review, adding sound to visual stimulus resulted in an increase in speed and efficiency. A possible reason for this difference between the expected and actual outcomes is that in the background cases of multimodal feedback, audio feedback was predominantly used to reinforce a decision or action by the user. In this experiment, audio feedback was used to identify individual elements of a list of choices.

Possible avenues of future research suggested by the experiment include variables such as the placement of the scrollbar, the speed of scrolling and the style in which the options are presented. In addition, experiments in which the scrollbar contains menu items instead of facts could also have interesting results, as would experiments that included sources of distraction for the user. Finally, the results of this experiment would seem particularly relevant to the design of applications intended for platforms with a limited view size, such as smart phones, and further research focusing specifically on such devices would seem to be useful.

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APPENDIX:

Data

Trial	Ctime	Ttime	Sright	Tright	Tdif	Rdiff
sound	50	45	9	9	-5	0
sound	52	34	9	9	-18	0
sound	57	46	9	8	-11	-1
sound	59	55	9	9	-4	0
sound	60	62	9	9	2	0
sound	62	61	6	6	-1	0
sound	62	58	9	9	-4	0
sound	63	16	9	9	-47	0
sound	64	66	9	9	2	0
sound	64	45	6	6	-19	0
sound	65	58	9	9	-7	0
sound	65	48	9	7	-17	-2
sound	66	68	6	6	2	0
sound	67	68	6	6	1	0
sound	68	78	9	9	10	0
sound	68	65	9	9	-3	0
sound	68	55	6	6	-13	0
sound	69	56	9	9	-13	0
sound	69	40	9	9	-29	0
sound	72	54	9	9	-18	0
sound	74	104	6	6	30	0
sound	75	82	9	9	7	0
sound	75	74	9	9	-1	0
sound	75	36	9	9	-39	0
sound	76	110	8	9	34	1
sound	76	98	8	9	22	1
sound	76	18	8	2	-58	-6
sound	77	98	9	9	21	0
sound	77	78	9	9	1	0
sound	77	72	9	9	-5	0
sound	77	69	9	9	-8	0
sound	78	59	9	9	-19	0
sound	78	57	6	6	-21	0
sound	79	91	4	6	12	2
sound	79	77	9	9	-2	0
sound	79	62	6	6	-17	0
sound	82	91	9	9	9	0
sound	82	69	9	9	-13	0
sound	82	23	9	6	-59	-3
sound	83	108	9	9	25	0
sound	83	75	6	6	-8	0
sound	83	72	9	9	-11	0
sound	83	71	9	9	-12	0
sound	84	79	6	6	-5	0
sound	84	63	5	6	-21	1
sound	85	24	6	0	-61	-6
sound	87	75	6	6	-12	0
sound	88	79	8	7	-9	-1

sound 88	73	9	8	-15	-1
sound 89	101	1	1	12	0
sound 89	36	9	9	-53	0
sound 90	91	6	6	1	0
sound 90	57	9	9	-33	0
sound 91	54	9	9	-37	0
sound 92	53	9	9	-39	0
sound 92	32	9	9	-60	0
sound 93	102	9	9	9	0
sound 94	75	9	9	-19	0
sound 94	69	9	9	-25	0
sound 95	104	9	9	9	0
sound 95	79	9	9	-16	0
sound 95	67	9	9	-28	0
sound 96	83	6	6	-13	0
sound 96	24	9	9	-72	0
sound 97	119	9	9	22	0
sound 97	31	9	9	-66	0
sound 98	60	4	4	-38	0
sound 98	43	9	9	-55	0
sound 99	80	6	6	-19	0
sound 100	82	6	6	-18	0
sound 101	25	6	6	-76	0
sound 103	2	7	0	-101	-7
sound 104	79	7	7	-25	0
sound 105	91	9	9	-14	0
sound 106	93	6	6	-13	0
sound 106	89	9	9	-17	0
sound 106	81	6	6	-25	0
sound 107	95	9	9	-12	0
sound 108	93	9	9	-15	0
sound 111	129	6	6	18	0
sound 113	69	9	9	-44	0
sound 114	89	6	6	-25	0
sound 116	104	6	5	-12	-1
sound 117	78	6	6	-39	0
sound 117	73	6	6	-44	0
sound 117	34	9	9	-83	0
sound 120	92	9	9	-28	0
sound 120	69	6	6	-51	0
sound 120	18	9	0	-102	-9
sound 122	74	9	9	-48	0
sound 127	122	8	8	-5	0
sound 127	108	6	6	-19	0
sound 131	68	8	9	-63	1
sound 132	106	9	9	-26	0
sound 136	89	9	8	-47	-1
sound 142	85	9	9	-57	0
sound 148	117	6	6	-31	0
sound 148	84	6	5	-64	-1
sound 152	76	6	6	-76	0
sound 157	106	9	9	-51	0
sound 164	104	8	9	-60	1
sound 175	131	9	9	-44	0
sound 205	153	8	9	-52	1
sound 209	16	8	2	-193	-6
sound 215	45	9	9	-170	0

sound	221	123	6	6	-98	0
sound	256	102	8	9	-154	1
sound	263	149	9	9	-114	0
move	107	347	6	6	240	0
move	98	138	9	9	40	0
move	185	127	6	6	-58	0
move	177	126	6	6	-51	0
move	125	120	9	9	-5	0
move	126	118	6	5	-8	-1
move	158	115	6	6	-43	0
move	190	108	9	9	-82	0
move	129	103	9	9	-26	0
move	95	103	9	9	8	0
move	93	98	9	9	5	0
move	189	96	6	6	-93	0
move	63	96	2	6	33	4
move	120	91	9	7	-29	-2
move	197	88	9	9	-109	0
move	115	87	9	8	-28	-1
move	108	85	7	7	-23	0
move	98	85	9	9	-13	0
move	86	85	9	9	-1	0
move	106	83	9	9	-23	0
move	174	82	8	9	-92	1
move	119	80	9	9	-39	0
move	121	79	6	6	-42	0
move	113	79	9	9	-34	0
move	105	79	9	9	-26	0
move	108	78	9	9	-30	0
move	176	77	6	9	-99	3
move	124	77	9	8	-47	-1
move	119	77	9	8	-42	-1
move	104	77	8	6	-27	-2
move	78	77	4	8	-1	4
move	201	76	9	9	-125	0
move	190	76	9	8	-114	-1
move	146	76	6	6	-70	0
move	95	76	6	6	-19	0
move	125	75	6	6	-50	0
move	103	74	9	9	-29	0
move	100	73	6	6	-27	0
move	88	73	9	9	-15	0
move	112	71	9	9	-41	0
move	92	70	8	9	-22	1
move	79	70	9	9	-9	0
move	74	70	9	9	-4	0
move	122	68	6	6	-54	0
move	158	67	6	6	-91	0
move	142	67	9	9	-75	0
move	112	67	9	9	-45	0
move	104	67	5	6	-37	1
move	98	67	9	9	-31	0
move	93	67	3	8	-26	5
move	68	67	9	8	-1	-1
move	58	67	9	9	9	0
move	152	66	6	6	-86	0
move	129	66	9	9	-63	0

move	96	66	6	6	-30	0
move	199	64	5	5	-135	0
move	118	64	6	6	-54	0
move	112	64	9	9	-48	0
move	107	64	6	6	-43	0
move	101	63	9	9	-38	0
move	71	63	6	5	-8	-1
move	166	62	8	6	-104	-2
move	111	62	6	6	-49	0
move	102	62	9	9	-40	0
move	101	62	9	6	-39	-3
move	90	62	9	9	-28	0
move	77	62	6	6	-15	0
move	60	62	6	6	2	0
move	88	61	9	9	-27	0
move	116	60	6	6	-56	0
move	91	59	9	9	-32	0
move	79	59	9	9	-20	0
move	75	59	5	5	-16	0
move	63	59	9	9	-4	0
move	212	58	0	6	-154	6
move	98	58	9	9	-40	0
move	91	58	9	8	-33	-1
move	83	58	8	8	-25	0
move	69	58	6	6	-11	0
move	58	58	9	8	0	-1
move	105	57	6	6	-48	0
move	79	55	6	6	-24	0
move	85	53	6	6	-32	0
move	56	53	9	8	-3	-1
move	194	52	6	6	-142	0
move	108	52	9	9	-56	0
move	86	51	9	9	-35	0
move	122	50	6	6	-72	0
move	85	48	9	8	-37	-1
move	54	48	9	9	-6	0
move	105	47	9	9	-58	0
move	80	47	9	9	-33	0
move	64	47	9	9	-17	0
move	76	46	6	6	-30	0
move	64	46	9	8	-18	-1
move	89	45	6	6	-44	0
move	66	45	6	6	-21	0
move	64	45	9	8	-19	-1
move	75	44	6	6	-31	0
move	72	43	8	6	-29	-2
move	55	43	9	9	-12	0
move	61	42	6	6	-19	0
move	72	41	6	6	-31	0
move	71	40	9	9	-31	0
move	72	39	9	9	-33	0
move	52	39	8	9	-13	1
move	77	38	9	4	-39	-5
move	116	35	6	6	-81	0
move	86	35	9	9	-51	0
move	128	34	6	6	-94	0
move	94	27	6	3	-67	-3

move	159	26	9	9		-133	0		
move	124	25	9	9		-99	0		
move	79	25	6	1		-54	-5		
move	61	25	0	0		-36	0		
move	75	21	9	9		-54	0		
move	104	17	9	4		-87	-5		
move	151	13	6	1		-138	-5		
move	100	11	6	0		-89	-6		
move	59	11	0	0		-48	0		
move	117	7	9	1		-110	-8		
soundandmove			94	81	9	9		-13	0
soundandmove			79	28	9	9		-51	0
soundandmove			93	73	9	7		-20	-2
soundandmove			100	102	8	7		2	-1
soundandmove			74	21	6	6		-53	0
soundandmove			208	171	6	6		-37	0
soundandmove			71	45	9	9		-26	0
soundandmove			59	57	9	9		-2	0
soundandmove			88	38	9	8		-50	-1
soundandmove			98	56	8	9		-42	1
soundandmove			121	74	6	6		-47	0
soundandmove			89	57	9	8		-32	-1
soundandmove			111	42	9	9		-69	0
soundandmove			90	64	6	6		-26	0
soundandmove			91	64	9	8		-27	-1
soundandmove			109	64	6	5		-45	-1
soundandmove			107	90	8	9		-17	1
soundandmove			109	64	8	8		-45	0
soundandmove			72	59	9	9		-13	0
soundandmove			60	43	6	5		-17	-1
soundandmove			71	53	9	9		-18	0
soundandmove			95	72	9	9		-23	0
soundandmove			112	100	1	6		-12	5
soundandmove			96	67	6	6		-29	0
soundandmove			105	57	9	2		-48	-7
soundandmove			116	5	9	0		-111	-9
soundandmove			73	67	6	6		-6	0
soundandmove			115	57	6	6		-58	0
soundandmove			62	26	7	8		-36	1
soundandmove			132	88	8	8		-44	0
soundandmove			173	99	8	8		-74	0
soundandmove			82	39	9	9		-43	0
soundandmove			114	96	1	3		-18	2
soundandmove			79	77	9	9		-2	0
soundandmove			112	64	6	6		-48	0
soundandmove			114	62	6	5		-52	-1
soundandmove			83	68	9	9		-15	0
soundandmove			79	60	9	9		-19	0
soundandmove			132	65	9	9		-67	0
soundandmove			89	85	9	9		-4	0
soundandmove			74	80	5	6		6	1
soundandmove			215	85	6	5		-130	-1
soundandmove			136	63	9	9		-73	0
soundandmove			125	69	9	9		-56	0
soundandmove			82	25	6	6		-57	0
soundandmove			170	106	8	8		-64	0
soundandmove			225	132	8	8		-93	0

soundandmove	68	51	9	9	-17	0
soundandmove	60	28	9	9	-32	0
soundandmove	116	13	9	1	-103	-8
soundandmove	74	78	9	8	4	-1
soundandmove	87	62	8	7	-25	-1
soundandmove	99	85	8	9	-14	1
soundandmove	81	64	9	8	-17	-1
soundandmove	149	89	9	9	-60	0
soundandmove	138	75	9	5	-63	-4
soundandmove	153	73	8	9	-80	1
soundandmove	77	37	9	9	-40	0
soundandmove	80	53	9	8	-27	-1
soundandmove	109	5	7	0	-104	-7
soundandmove	73	73	6	6	0	0
soundandmove	73	25	9	9	-48	0
soundandmove	148	62	6	6	-86	0
soundandmove	88	6	6	0	-82	-6
soundandmove	99	50	6	6	-49	0
soundandmove	107	46	9	8	-61	-1
soundandmove	84	58	9	8	-26	-1
soundandmove	93	22	9	9	-71	0
soundandmove	149	102	9	9	-47	0
soundandmove	107	24	6	6	-83	0
soundandmove	77	71	9	9	-6	0
soundandmove	54	-296	0	0	-350	0
soundandmove	84	47	2	1	-37	-1
soundandmove	94	56	6	6	-38	0
soundandmove	149	92	9	9	-57	0
soundandmove	54	30	9	9	-24	0
soundandmove	94	76	9	8	-18	-1
soundandmove	77	33	9	7	-44	-2
soundandmove	77	34	9	9	-43	0
soundandmove	66	44	9	9	-22	0
soundandmove	60	97	0	8	37	8
soundandmove	88	67	9	9	-21	0
soundandmove	92	59	2	1	-33	-1
soundandmove	21	28	0	0	7	0
soundandmove	76	72	9	8	-4	-1
soundandmove	57	64	6	6	7	0
soundandmove	108	74	8	9	-34	1
soundandmove	111	65	6	6	-46	0
soundandmove	112	82	9	8	-30	-1
soundandmove	87	62	6	6	-25	0
soundandmove	152	82	6	6	-70	0
soundandmove	136	81	9	9	-55	0
soundandmove	90	29	6	6	-61	0
soundandmove	59	70	6	6	11	0
soundandmove	168	98	9	9	-70	0
soundandmove	78	92	9	8	14	-1
soundandmove	109	80	9	9	-29	0
soundandmove	80	48	8	8	-32	0
soundandmove	71	41	6	6	-30	0
soundandmove	81	70	9	9	-11	0
soundandmove	206	105	9	7	-101	-2
soundandmove	107	75	7	8	-32	1
soundandmove	75	50	8	9	-25	1
soundandmove	97	72	9	9	-25	0

soundandmove	171	33	9	9	-138	0
soundandmove	62	58	9	9	-4	0
soundandmove	71	59	9	9	-12	0
soundandmove	101	61	9	9	-40	0
soundandmove	78	27	6	0	-51	-6
soundandmove	138	108	6	6	-30	0
soundandmove	95	5	7	0	-90	-7
soundandmove	151	98	6	6	-53	0
soundandmove	123	72	9	8	-51	-1
soundandmove	76	63	9	8	-13	-1
soundandmove	95	63	9	8	-32	-1
soundandmove	89	114	0	9	25	9
soundandmove	134	44	9	9	-90	0
soundandmove	108	64	6	6	-44	0
soundandmove	83	49	9	8	-34	-1
soundandmove	91	60	9	7	-31	-2
soundandmove	70	45	9	9	-25	0

SAS Output

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                                          The SAS System
                                         The GLM Procedure

                                     Class Level Information
                            Class         Levels    Values
                            Trt                3    move sound soundand

                              Number of Observations Read         350
                              Number of Observations Used         350


Dependent Variable: CtrlTime

                                                Sum of
        Source                     DF          Squares     Mean Square    F
Value    Pr > F

        Model                       2        2097.8129       1048.9065
0.74    0.4770

        Error                     347      490681.1156       1414.0666

        Corrected Total           349      492778.9286


                       R-Square     Coeff Var      Root MSE    CtrlTime Mean

                       0.004257      36.64604      37.60408         102.6143


        Source                     DF        Type I SS     Mean Square    F
Value    Pr > F

        Trt                         2      2097.812945     1048.906473
0.74    0.4770


        Source                     DF      Type III SS     Mean Square    F
Value    Pr > F

        Trt                         2      2097.812945     1048.906473
0.74    0.4770

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                                           The SAS System

                                         The GLM Procedure

Dependent Variable: TrtTime

                                                 Sum of
        Source                     DF          Squares     Mean Square    F
Value    Pr > F

        Model                       2        9998.8257       4999.4129
3.80    0.0234
```

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Error	347	457040.0429	1317.1183		
Corrected Total	349	467038.8686			

R-Square	Coeff Var	Root MSE	TrtTime Mean
0.021409	55.19355	36.29212	65.75429

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Trt	2	9998.825719	4999.412859	3.80	0.0234

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Trt	2	9998.825719	4999.412859	3.80	0.0234

The SAS System

The GLM Procedure

Dependent Variable: CtrlCorrect

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	10.226942	5.113471	1.32	0.2697
Error	347	1349.033058	3.887703		
Corrected Total	349	1359.260000			

R-Square	Coeff Var	Root MSE	CtrlCorrect Mean
0.007524	26.01222	1.971726	7.580000

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Trt	2	10.22694215	5.11347107	1.32	0.2697

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Trt	2	10.22694215	5.11347107	1.32	0.2697

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                                       The SAS System

                                     The GLM Procedure

Dependent Variable: TrtCorrect

                                            Sum of
        Source                      DF         Squares     Mean Square    F
Value    Pr > F

        Model                        2       12.251216        6.125608
1.17    0.3116

        Error                      347     1816.917355        5.236073

        Corrected Total            349     1829.168571

                      R-Square     Coeff Var      Root MSE    TrtCorrect Mean

                      0.006698      31.66810      2.288247           7.225714

        Source                      DF       Type I SS     Mean Square    F
Value    Pr > F

        Trt                          2     12.25121606      6.12560803
1.17    0.3116

        Source                      DF     Type III SS     Mean Square    F
Value    Pr > F

        Trt                          2     12.25121606      6.12560803
1.17    0.3116

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                                       The SAS System

                                     The GLM Procedure

Dependent Variable: TimeDiff

                                            Sum of
        Source                      DF         Squares     Mean Square    F
Value    Pr > F

        Model                        2      11751.8514       5875.9257
3.37    0.0356

        Error                      347     605538.2886       1745.0671

        Corrected Total            349     617290.1400

                       R-Square     Coeff Var      Root MSE    TimeDiff Mean

                       0.019038     -113.3315      41.77400        -36.86000
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       Source                      DF       Type I SS     Mean Square    F
Value    Pr > F

       Trt                          2     11751.85143      5875.92572
3.37    0.0356


       Source                      DF     Type III SS     Mean Square    F
Value    Pr > F

       Trt                          2     11751.85143      5875.92572
3.37    0.0356

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                                                The SAS System

                                              The GLM Procedure

Dependent Variable: CorrectDiff

                                                     Sum of
       Source                      DF         Squares     Mean Square    F
Value    Pr > F

       Model                        2        1.407414        0.703707
0.21    0.8130

       Error                      347     1178.661157        3.396718

       Corrected Total            349     1180.068571

                     R-Square     Coeff Var      Root MSE    CorrectDiff Mean

                     0.001193     -520.2069      1.843019           -0.354286

       Source                      DF       Type I SS     Mean Square    F
Value    Pr > F

       Trt                          2      1.40741440      0.70370720
0.21    0.8130


       Source                      DF     Type III SS     Mean Square    F
Value    Pr > F

       Trt                          2      1.40741440      0.70370720
0.21    0.8130

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                                                The SAS System

                                              The GLM Procedure

                                   Waller-Duncan K-ratio t Test for CtrlTime
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    NOTE: This test minimizes the Bayes risk under additive loss and certain
other assumptions.


                              Kratio                                100
                              Error Degrees of Freedom              347
                              Error Mean Square                1414.067
                              F Value                              0.74
                              Critical Value of t               2.45188
                              Minimum Significant Difference     12.089
                              Harmonic Mean of Cell Sizes      116.3323

                                  NOTE: Cell sizes are not equal.


                         Means with the same letter are not significantly different.


                       Waller Grouping          Mean      N    Trt

                                 A       105.975    121    move
                                 A
                                 A       101.046    108    sound
                                 A
                                 A       100.653    121    soundand

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                                           The SAS System

                                         The GLM Procedure

                              Waller-Duncan K-ratio t Test for TrtTime

    NOTE: This test minimizes the Bayes risk under additive loss and certain
other assumptions.


                              Kratio                                100
                              Error Degrees of Freedom              347
                              Error Mean Square                1317.118
                              F Value                              3.80
                              Critical Value of t               2.02611
                              Minimum Significant Difference     9.6414
                              Harmonic Mean of Cell Sizes      116.3323

                                  NOTE: Cell sizes are not equal.


                        Means with the same letter are not significantly different.


                         Waller Grouping          Mean      N    Trt

                                   A        72.852    108    sound
                                   A
                              B    A        65.554    121    move
                              B
                              B             59.620    121    soundand

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The SAS System

The GLM Procedure

Waller-Duncan K-ratio t Test for CtrlCorrect

NOTE: This test minimizes the Bayes risk under additive loss and certain other assumptions.

Kratio	100
Error Degrees of Freedom	347
Error Mean Square	3.887703
F Value	1.32
Critical Value of t	2.33386
Minimum Significant Difference	0.6034
Harmonic Mean of Cell Sizes	116.3323

NOTE: Cell sizes are not equal.

Means with the same letter are not significantly different.

Waller Grouping	Mean	N	Trt
A	7.8333	108	sound
A			
A	7.4959	121	soundand
A			
A	7.4380	121	move

The SAS System

The GLM Procedure

Waller-Duncan K-ratio t Test for TrtCorrect

NOTE: This test minimizes the Bayes risk under additive loss and certain other assumptions.

Kratio	100
Error Degrees of Freedom	347
Error Mean Square	5.236073
F Value	1.17
Critical Value of t	2.36174
Minimum Significant Difference	0.7086
Harmonic Mean of Cell Sizes	116.3323

NOTE: Cell sizes are not equal.

Means with the same letter are not significantly different.

Waller Grouping	Mean	N	Trt
A	7.5000	108	sound

```
                    A
                    A        7.1488    121    move
                    A
                    A        7.0579    121    soundand
```


The SAS System

The GLM Procedure

Waller-Duncan K-ratio t Test for TimeDiff

NOTE: This test minimizes the Bayes risk under additive loss and certain other assumptions.

Kratio	100
Error Degrees of Freedom	347
Error Mean Square	1745.067
F Value	3.37
Critical Value of t	2.06133
Minimum Significant Difference	11.291
Harmonic Mean of Cell Sizes	116.3323

NOTE: Cell sizes are not equal.

Means with the same letter are not significantly different.

```
Waller Grouping          Mean      N    Trt

              A       -28.194    108    sound

              B       -40.421    121    move
              B
              B       -41.033    121    soundand
```


The SAS System

The GLM Procedure

Waller-Duncan K-ratio t Test for CorrectDiff

NOTE: This test minimizes the Bayes risk under additive loss and certain other assumptions.

Kratio	100
Error Degrees of Freedom	347
Error Mean Square	3.396718
F Value	0.21
Critical Value of t	2.58214
Minimum Significant Difference	0.624
Harmonic Mean of Cell Sizes	116.3323

NOTE: Cell sizes are not equal.

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              Means with the same letter are not significantly different.


            Waller Grouping          Mean      N    Trt

                          A       -0.2893    121    move
                          A
                          A       -0.3333    108    sound
                          A
                          A       -0.4380    121    soundand
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                                  The SAS System

                                The CORR Procedure

                           1 With Variables:    CtrlTime
                           1      Variables:    TrtTime


                                Simple Statistics

     Variable           N          Mean       Std Dev           Sum
Minimum       Maximum

     CtrlTime         350     102.61429      37.57624         35915
21.00000     263.00000
     TrtTime          350      65.75429      36.58169         23014
-296.00000     347.00000


                    Pearson Correlation Coefficients, N = 350
                            Prob > |r| under H0: Rho=0

                                             TrtTime

                             CtrlTime       0.35700
                                             <.0001

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                                  The SAS System

--------------------------------------------- Trt=move
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                                The CORR Procedure

                           1 With Variables:    CtrlTime
                           1      Variables:    TrtTime


                                Simple Statistics
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    Variable           N          Mean       Std Dev           Sum
Minimum       Maximum

    CtrlTime         121     105.97521      37.69427         12823
52.00000     212.00000
    TrtTime          121      65.55372      35.55956          7932
7.00000     347.00000


                             Pearson Correlation Coefficients, N = 121
                                     Prob > |r| under H0: Rho=0

                                                    TrtTime

                                       CtrlTime       0.25990
                                                       0.0040

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                                            The SAS System

-------------------------------------------- Trt=sound
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                                          The CORR Procedure

                                    1 With Variables:    CtrlTime
                                    1      Variables:    TrtTime


                                          Simple Statistics

    Variable           N          Mean       Std Dev           Sum
Minimum       Maximum

    CtrlTime         108     101.04630      40.10253         10913
50.00000     263.00000
    TrtTime          108      72.85185      29.33653          7868
2.00000     153.00000


                             Pearson Correlation Coefficients, N = 108
                                     Prob > |r| under H0: Rho=0

                                                    TrtTime

                                       CtrlTime       0.42103
                                                       <.0001

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                                            The SAS System

------------------------------------------- Trt=soundand
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                                          The CORR Procedure

                                    1 With Variables:    CtrlTime
                                    1      Variables:    TrtTime
```

Simple Statistics

Variable	N	Mean	Std Dev	Sum	Minimum	Maximum
CtrlTime	121	100.65289	35.13064	12179	21.00000	225.00000
TrtTime	121	59.61983	42.15196	7214	-296.00000	171.00000

Pearson Correlation Coefficients, N = 121
Prob > |r| under H0: Rho=0

	TrtTime
CtrlTime	0.42930 <.0001