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Effects of input modality and expertise on workload and video game performance

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EFFECTS OF INPUT MODALITY AND EXPERTISE ON WORKLOAD AND
VIDEO GAME PERFORMANCE

by

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A thesis submitted in partial fulfillment of the requirements
for the Honors in the Major Program in Psychology
in the College of Sciences
and in The Burnett Honors College
at the University of Central Florida
Orlando, Florida

Fall Term 2011

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Abstract

A recent trend in consumer and military electronics has been to allow operators the option to control the system via novel control methods. The most prevalent and available form of these methods is that of vocal control. Vocal control allows for the control of a system by speaking commands rather than manually inputting them. This has not only implications for increased productivity but also optimizing safety, and assisting the disabled population. Past research has examined the potential costs and benefits to this novel control scheme with varying results. The purpose of this study was to further examine the relationship between modality of input, operator workload, and expertise. The results obtained indicated that vocal control may not be ideal in all situations as a method of input as participants experienced significantly higher amounts of workload than those in the manual condition. Additionally, expertise may be more specific than previously thought as participants in the vocal condition performed nearly identical at the task regardless of gaming expertise. The implications of the findings for this study suggest that vocal control be further examined as an effective method of user input, especially with regards to expertise and training effects.

Dedication

I would like to dedicate this thesis to the most important and influential person in my life, my mother. I would be nowhere near where I am today if it were not for you. The least I can do is dedicate this work to you, I love you Mom.

Acknowledgments

I would like to acknowledge Dr. Valerie Sims for her invaluable guidance and supervision during my time on this project. Thank you for seeing in me what I did not know was there and motivating me to success.

I would also like to thank Matthew Marraffino for assisting me with my project and always being available whenever I needed help. Without you this study would not have been possible.

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Introduction

There has been a recent trend in consumer electronics that has led to the development of such products as the Microsoft Kinect, Ford Sync and Apple's Siri. All of these products owe their existence to consumers clamoring for alternative ways to operate and control devices; devices, that since their inception, have been controlled via tactile methods e.g. mouse and keyboard or game controller. These products also share a common attribute which allows users to control them using only their voice rather than standard manual controls. Previous research has indicated that there are possible benefits as well as potential costs to the implementation of vocal control systems.

Working Memory and Workload

Multitasking and short-term memory have long been subjects of research in psychology. Baddeley and Hitch (1974) proposed working memory, a model, they define as "a limited capacity system, which temporarily maintains and stores information, supports human thought processes by providing an interface between perception, long-term memory and action" (Baddeley, 2004). Included in working memory model are two slave systems that operate the working memory: the phonological loop and the visio-spatial sketch pad. The phonological loop stores language or phonological information. It is called a loop because it continues to rehearse information to prevent it from decaying. The visio-spatial sketch pad's role is to store visual and spatial information or to manipulate mental images such as maps or figures. Directing the two slave systems is the central executive. The central executive's role is to decide what needs to be attended to and how many resources should be allocated to certain tasks. An important feature of

Baddeley's working memory model is that a person can experience both visual and phonological information without a decrease in quality because different systems operate them.

Wickens (1980) later expanded on Baddeley's model of working memory and, developed a three dimensional model termed multiple resource theory. His model is based on three aspects: codes, modalities, and stages. A fourth aspect, visual processing was added later. Codes of processing involve either spatial or verbal activity. Modality refers to perception either of a visual or verbal nature, (e.g. seeing a drawing of a map or hearing directions to a destination). Stages of processing is the only aspect that is not dichotic, rather it has three parts. Perception, then cognition, and at the other end, responding. As stated earlier, Wickens built upon Baddeley's idea of the independent slave systems for his model. Visual activity uses different resources than auditory activity. Verbal activity uses different resources than spatial activity. They can both be operated at the same time with little degradation. Wickens (2008) discusses how workload and his multiple resource model are related.

Wickens discusses how multiple resource theory and workload are similar. They overlap, but have distinctions. Workload can be defined as "a hypothetical construct that represents the cost incurred by a human operator to achieve a particular level of performance" (Hart, Staveland, 1988). The multiple resource model is characterized by demand, resource overlap, and allocation policy with workload being most closely related to demand. The best situation for the operator is to have less demand than the limit of resources. Less demand during a task allows the operator to compensate for additional workload that may occur. Too much workload results in performance degradation. Workload and the multiple resource 3D+1 model can be combined by thinking of

the amount of operator's workload as volume in a given cube. When the amount of volume does not exceed the capacity of the cube, the task is done efficiently. But when the demand outweighs the capacity, performance will suffer (Wickens 2008).

However, expertise in a domain appears to mitigate workload for an individual. Simon and Chase (1973) studied chess player's abilities to recall chess boards with pieces on them. The study was a two by two design with expert and novice players, and the position of pieces being either at random or being from an actual played game. The results were that expert players were more able to remember boards only with pieces that were from actual games. Novice players were poor at both actual and random boards. Their conclusion was that expert players used chunking strategies that allowed them to handle more pieces of information, allowing them to memorize more pieces on the board.

Research has indicated that expertise in a domain mitigates the effects of workload. Zeng (2009) conducted a study of expert and non expert surgeons. Participants would take part in a primary task, simulation of laparoscopic suturing, where they would make as many sutures as quickly as possible without sacrificing quality. While doing the first task, participants would also have to perform a secondary task. This was a signal detection task where participants would respond to images presented to them on an adjacent computer screen. The results indicated that surgeons with more experience have developed skills to better assist them during a laparoscopic procedure. These skills are used to free up more cognitive resources and allow them to attend to a secondary task better than those with less experience.

Video Game Research

Video games have been shown to be more than simply a form of entertainment, they can be useful tools in teaching and training. Sims and Mayer (2002) examined the possibility of video game players extending their expertise of a particular video game into other facets of cognition, in this instance, mental rotation. The study involved two experiments. The first involved determining if expert video game players of Tetris were able to translate their skill of mentally rotating block figures to other mental rotation tasks. The second examined training effects of Tetris on non-experts. For both experiments the results indicated that spatial ability is highly domain specific. The expert Tetris players were just as good as the non-experts and used the same methods of mental rotation. That is, that an expert at Tetris is very good at rotating Tetris blocks mentally and nothing else. The exact range of the domain of expertise however was not determined. The expertise of Tetris players may also be limited to specifically how they control the game.

Later research conducted by Green and Bavelier (2003) further examined the effects of training from video game play. Expert and non-expert video game players were utilized for this study. The study involved how receiving training from a video game could affect cognitive abilities, specifically selective attention. Video game players and non-video game players were recruited for the study. Participants both of the playing and non-playing groups took attention tests to ascertain their selective attention abilities. The results demonstrated that video game players outperformed non video game players at the attention tasks. The researchers were concerned however, that the results they had found may have simply been the result of

population differences between novice and expert video game players. To test for this, they designed a training experiment to see if non video game players could improve their selective attention. For one hour per day for ten consecutive days, non video game players played games after which they were tested. The results showed that after training, the non video game players demonstrated a significant improvement in their attentional abilities.

Vocal Control Research

In the past few years, recent research has looked at the possibility of new methods of control in operator procedures. The most prevalent and researched modality is that of vocal control. Vocal control is a way for an operator to assume control, either fully or partially, using his or her voice as a means of input rather than solely manual methods. Herdman, Johannsdottir, Lessard, Jarmasz, Churchill, Farrell (2001) conducted a study to determine the possible costs and or benefits of implementing a means of vocal control in a multi-crew helicopter. The study aimed to determine if the addition of a Direct Voice Input (DVI) would be able to aid the pilot and co-pilot in their respective duties. The possible benefits to the successful implementation of a DVI could lower the amount of workload put on the co-pilot, and free their attention from the aircraft control panel so that they may allocate their resources elsewhere as they see fit. It is also important to note that the co-pilot in no way is responsible for flying the aircraft, only aiding tasks such as communication and navigation.

Twelve pilot and co-pilot pairs were used for the research. The study was carried out on flight simulators to ensure safety and ease of data collection. From the data collected, mixed results were found. The co-pilots in the DVI condition showed a significant advantage in their

response times when responding to visual targets. The responses to auditory targets were not significantly different. The flying pilots however showed a significant disadvantage when using the DVI system for responding to both auditory and visual targets. The researchers concluded that the implementation of a vocal control method does allow for resource reallocation. That being said some of the reallocation is good while some of it is bad and they must be weighed upon each other.

A very large portion of speech control studies have come from the military sector. Creating an optimal platform for soldiers operating weapons and other military hardware is of great interest to the armed forces. Reddin, Carstens, Pettitt, (2010) conducted a study where soldiers would be in control of a robot either by means of a standard Xbox 360 controller or with vocal control. The soldiers controlled the robot through certain environments and executed certain tasks including taking reconnaissance pictures. The researchers hypothesized that soldiers using vocal control would be faster than manual control when doing simultaneous tasks and when accessing menu items but slower in operation of continuous tasks. Both hypotheses were met in the study. This is in line with Wickens' multiple resource theory. For instance, soldiers were faster at writing down numbers if they were using vocal control rather than tactile control. According to multiple resource theory, this is because manual/spatial responses utilize different resources than vocal/verbal responses, thus freeing up cognitive resources.

Other research has indicated that speech control, while in its infancy, has certain advantages; it is better for navigating menus, enabling the user to work faster and more accurately, and in simultaneous tasks it creates more efficiency but only for discrete tasks, not

continuous ones. (Chen, Hass, Pillalamarri, and Jacobson, 2006; Bortolussi and Vidulich, 1991, Pettitt, Redden, and Carstens, 2009)

The purpose of this study was to further examine the relationship between input modalities and the workload within a video game setting. The researcher was also interested in the relationship between expertise and workload, more specifically, how expertise in video games mitigates the workload required to use novel input abilities. The researcher proposed the following hypotheses:

- Hypothesis one: Participants in the vocal control condition will experience less workload than those in the controller condition. This falls in line with Wickens' model of multiple resource theory. Since the participants are doing a visual spatial task, responding vocally should free up more resources to the operator by distributing the workload across multiple aspects.
- Hypothesis two: The vocal condition participants will perform better at the task than the tactile control. For the same reasons above in hypothesis one, participants responding verbally rather than manually should have more resources available to them, thus allowing them to respond quicker to the task and in turn, perform better.
- Hypothesis three: Participants with higher gaming experience will experience less workload during the task than those with lower gaming experience. This should be because participants with higher experience in video games can chunk and are familiar with what is involved in successful video game strategies.

- Hypothesis four: Participants with higher video gaming experience will perform better than those participants with lower gaming experience. For the same reasons as in hypothesis three, expert gamers are familiar with what it takes to be successful in a video game task.

Method

Participants

Forty-five participants were used for this study. All participants were psychology students recruited from SONA Systems in exchange for partial or extra credit in a course. Exclusion factors include only native English speaking males, eighteen years or older.

Materials

The Gaming Experience Measure (GEM), validated for measuring a person's experience with video games was used to ascertain video game expertise: high or low (Taylor, Singer, Jerome, 2009). Participants completed the NASA Task Load Index Scale (TLX), a validated measure for determining the amount of workload experienced by the user during a given task. Workload is comprised of six subscales; Mental Demand, Physical Demand, Temporal Demand, Effort, Performance, and Frustration Level. All of these subscales are weighed and combined to produce one number for workload experienced (Hart, Staveland, 1988).

Apparatus

Games were played on the Microsoft Xbox 360 gaming console displayed on a 32inch Sony Bravia LCD HDTV. Both the controller and headset used for game control are of the official Microsoft brand that comes included with every console. The game being played is Tom Clancy's EndWar, a real-time strategy game developed by Ubisoft Shanghai.

Design

The study is a 2 (gaming expertise) by 2 (control method), between groups design. The factors of the design are gaming experience and method of control. Gaming experience is

comprised of two levels, high and low experience. These levels were determined by doing a median split of the participants' scores. Experience level was ascertained by participants completing the GEM. Method of control also had two levels. Participants either controlled the game by standard controller, or by vocal commands spoken into a headset. For this study the independent variable has two levels, game experience and method of control. Performance in the game was recorded through several variables; wins and losses, match duration, number of units survived, number of units destroyed and killed, number of enemies destroyed and killed, combat skill, mobility rating, and combat rating. To quantify performance in the game, the number of a participants units defeated was subtracted from the number of enemy units they managed to destroy. The higher the number, the better at the task they did with a positive number signifying a victory and a negative number demonstrating a loss.

Procedure

Participants came to the research area after being recruited through SONA systems. The researcher briefly explained the purpose of the experiment and answered any questions the participant had. After, participants were trained on how to play the game. Depending on which condition a participant is randomly assigned, they were given one of two training sessions. The training was done by the game itself which cuts down on variation of instruction by the researcher. Each session trains the participant on whichever method of control they will be using for the experiment and both deliver the same amount of instruction. The training consists of explaining the game, its objectives, and how to control the game. It also gives an opportunity to become acquainted with the game.

Once the participants had become familiar with the controls and methods of game play, they played two full length matches against the computer opponent. The map used was one of the larger ones in the game. The computer opponent's skill level was set to the medium difficulty. This was done to prevent a floor or ceiling effect.

Participants played the assault game mode. This mode's objective is to simply eliminate all enemy units. This game mode was chosen because of its simplicity to the users. Each condition started the participant with the same number of units, eight in total. No time limit on the games was placed. At the conclusion of the second match participants were directed to complete the NASA TLX, and Gaming Experience Measure.

Results

Analysis

Two 2X2 ANOVA's were carried out for this analysis. The first ANOVA was 2(input) x 2(gaming expertise) and was performed to investigate workload differences in workload. A main effect was found for. $F(3,41) = 5.22, p = .028$. A similar 2x2 ANOVA was performed to investigate differences in game performance. An interaction effect was found for this analysis. $F(3,41) = 4.81, p = .033$. There was no main effect for condition or gaming expertise. A Tukey HSD post-hoc analysis revealed a significant difference between high and low gamers in the controller condition but no significant difference in the vocal condition.

		Task Performance			Workload	
		<i>M</i>	<i>SD</i>	<i>n</i>	<i>M</i>	<i>SD</i>
Manual	High GEM	7.7	11.4	9	55	13.6
	Low GEM	-5.6	7.3	13	49.6	14.1
Vocal	High GEM	-0.7	9.4	14	63.7	14
	Low GEM	0.2	13.5	9	59.9	13

Table 1: Descriptive Statistics

Figure 1: Task Performance

Figure 2: Participant Workload

Discussion

The results of this study indicated that controlling the game by means of vocal input created significantly more workload for the user than that of manual input. Additionally, being an expert in the domain of video games did not make a significant difference in game performance. In fact, expert and non-expert gamers performed nearly identically. These findings did not support any of the research hypothesis previously stated. We suspect this is due to a number of factors. First, Pettitt, Redden, Carstens, (2009) found that one of the most important aspects to successful implementation of vocal control is to allow the operator to speak naturally. Prohibiting them from saying what they would naturally say or confining them to a rigid set of commands erases nearly all effectiveness of vocal input. This may have been the case in the present study. Participants were to memorize a set of commands that they would use to play the game. They also had to memorize exactly how the phrases were to be said. A very common mistake observed during game play was that participants would transpose words in the desired command strings. So when trying to change perspective from one unit to another by saying “Unit-One-Camera”, frequently they would say “Camera-Unit-One” or something similarly incorrect. While both statements convey the same information in English, syntactically they are wrong. It is conceivable that since the participants in the vocal condition experienced higher workload, that they were forced to reallocate their attention to their control method and away from the game, thus prohibiting them from performing as well as was predicted.

Another possible reason for observing the results that we did is that we did not allow for enough training time for participants to become familiar with the novel control method.

Herdman, et. al, (2001) proposed as well that increased training time on a vocal input system

could lower the attentional costs and workload experienced by the user. Perhaps being a novel system like vocal control requires longer than usual time for training.

Additionally, in the preliminary stages of this study, the researcher struggled with what the research hypothesis should be. The literature suggested that the expert gamers in the vocal condition would perform significantly better at the game and experience less workload than non-expert gamers in the manual condition. Anecdotally however, the researcher had experienced the opposite before the study was ever considered. Expert gamers seemed to get extremely frustrated by the game and even performing subpar due to their lack of familiar controller.

These findings suggest that expertise may be more specialized than previously thought. Sims and Mayer (2002) demonstrated how expertise in a domain does not translate to other related areas. Expert Tetris players were only experts in rotating Tetris style blocks. In the current study, expert video game players only performed like experts in the controller condition. That is, experts only did well when they were using what was familiar to them, a gaming controller. Perhaps expertise is not only specific to a domain but also to the method of control used in that domain.

The current study also has implications for how theories such as working memory, expertise, and workload are applied. If vocal input takes more time for operators to become familiar and proficient at it than standard manual control does, implementation of this method needs to be addressed accordingly. Simply adding a hands-free option for driving aids such as cell phones or GPS units may not be as safe as previously thought. Also, research by Herdman, et. al, (2001) and Pettitt, et. al, (2009) found that implementation of a voice command system was beneficial for certain tasks such a menu navigation or enumeration tasks but detrimental to

tasks that involved high level attentional resources such as flying a helicopter or unmanned drone. Herdman, et. al, (2001) suggested that training may help in making the operators better at the tasks but also suggested that pilots may not want to use vocal control whatsoever. Perhaps there are simply some areas that vocal control is infeasible or ill-suited to the task.

There were however some limitations to the present study. Due to time constraints, a less than optimal amount of participants were obtained. Ideally the study would have received more than double the current amount of participants. Also due to time constraints was the exclusion of several measures and tests that were collected from participants. Heart rate variability (HRV), presence in the game, and mental rotation were all collected but not analyzed for this current study.

There are several avenues that future research could further explore using the findings from this study. Researchers should further investigate the effects of training on vocal input systems. How much of a learning curve is associated with using ones voice to control a system and how far to the possible benefits reach? Also, are there situations where a vocal control system is not feasible, and if so what are the criterion for these situations? Researchers should also further examine the idea of mixing modalities for controlling systems. Perhaps it is not best for an operator to control a system solely by manual or vocal methods but rather by a blending of the two. Future research into the topic of vocal input and human computer interaction promises to be a topic that is both full of possibilities and opportunities.

APPENDIX A : SCREEN CAPTURE OF VIDEO GAME

APPENDIX B : GAME LEXICON

Who	What	Where
Unit	Attack	Target
Air Strike	Secure	Alpha
Force Recon	Upgrade	Bravo
Electronic Warfare	Move To	Delta
WMD	Retreat	Foxtrot
Deploy	Camera	Kilo
Landing Zone		Lima
Crash		

APPENDIX C : NASA TLX

Task Questionnaire - Part 1

Click on each scale at the point that best indicates your experience of the task

Mental Demand

--	--	--	--	--	--	--	--	--	--

Low High

Physical Demand

--	--	--	--	--	--	--	--	--	--

Low High

Temporal Demand

--	--	--	--	--	--	--	--	--	--

Low High

Performance

--	--	--	--	--	--	--	--	--	--

Good Poor

Effort

--	--	--	--	--	--	--	--	--	--

Low High

Frustration

--	--	--	--	--	--	--	--	--	--

Low High

Cancel

Continue

Task Questionnaire - Part 2

Click on the factor that represents the more important contributor to workload for the task

Effort

or

Physical Demand

Task Questionnaire - Part 2

Click on the factor that represents the more important contributor to workload for the task

Temporal Demand

or

Mental Demand

Task Questionnaire - Part 2

Click on the factor that represents the more important contributor to workload for the task

Performance

or

Frustration

APPENDIX D : GAMING EXPERIENCE MEASURE

GEM

GEM

Video Game Related Questions

Answer the questions below to characterize your previous experience with video and computer games. For each question select the appropriate choice that most accurately describes your experience. Answer questions independently in the order that they appear. Do not skip questions or return to a previous question to change your answer.

What is your level of confidence with video games in general?

Choose one of the following answers

- ☐ Very Low
- ☐ Low
- ☐ Average
- ☐ High
- ☐ Very High

What is your level of experience with video games in general?

Choose one of the following answers

- ☐ Very Little
- ☐ Less than Average
- ☐ Average
- ☐ More than Average
- ☐ Very High

How many hours per week do you currently play video games (average of the past 6 months)? Choose one of the following answers

- ☐ 0 hours
- ☐ 1-10 hours
- ☐ 11-20 hours
- ☐ 21-30 hours
- ☐ 31+ hours

What is the maximum number of hours per week you've ever spent playing video games?
Choose one of the following answers

- ☐ 0 hours
- ☐ 1-5 hours
- ☐ 6-10 hours
- ☐ 11-15 hours
- ☐ 16+ hours

About how many times have you read a video game magazine or website to find out tips to improve your gaming skill?
Choose one of the following answers

- ☐ 0 times
- ☐ 1-5 times
- ☐ 6-10 times
- ☐ 11-15 times
- ☐ 15+ times

Do you own a video game console?

- ☐ Yes ☐ No

Which game platform do you play with the most?
Check any that apply

- ☐ Sony Playstation 2
- ☐ Sony Playstation 3
- ☐ Sony Playstation Portable
- ☐ Nintendo Wii
- ☐ Nintendo DS
- ☐ Microsoft Xbox
- ☐ Microsoft Xbox 360
- ☐ Computer
- ☐ Other

Which game platform do you prefer?
Check any that apply

- ☐ Sony Playstation 2
☐ Sony Playstation 3
☐ Sony Playstation Portable
☐ Nintendo Wii
☐ Nintendo DS
☐ Microsoft Xbox
☐ Microsoft Xbox 360
☐ Computer
☐ Other

How much experience do you have with each of these types of games? If you play a game that fits in more than one category, include it for all relevant categories.

	Never	Rarely	Monthly	Weekly	Daily
Action (e.g., Street Fighter, Contra)	☐	☐	☐	☐	☐
Adventure (e.g., Myst, Fable)	☐	☐	☐	☐	☐
Music (e.g., Guitar Hero, Dance Dance Revolution)	☐	☐	☐	☐	☐
Platform (e.g., Mario Bros., Sonic the Hedgehog)	☐	☐	☐	☐	☐
Puzzle (e.g., Minesweeper, Tetris)	☐	☐	☐	☐	☐
Racing (e.g., Need for Speed, Test Drive)	☐	☐	☐	☐	☐
Role-playing (e.g., Final Fantasy,	☐	☐	☐	☐	☐

Pokemon)					
Shooter					
(e.g., Doom, Halo)					
Simulation					
(e.g., Flight Simulator, SimCity)					
Sports (e.g., Madden Football, FIFA Soccer)					
Strategy (e.g., Command and Conquer, Civilization)					

List your 5 favorite video game titles, and rate your experience with them below:

- A
- B
- C
- D
- E

Indicate your experience with each game you listed in question above (select "None" for any items left blank):

		Very			
	None	Little	Average	High	Expert
A	☐	☐	☐	☐	☐
B	☐	☐	☐	☐	☐
C	☐	☐	☐	☐	☐
D	☐	☐	☐	☐	☐
E	☐	☐	☐	☐	☐

List the gaming systems you have the most

experience with. Generic devices, such as PCs and phones, can be included if you have experience using them to play video games:

- A
- B
- C
- D
- E

Indicate your experience with each system you listed in question above (select "None" for any items left blank):

	None	Very Little	Average	High	Expert
A	☐	☐	☐	☐	☐
B	☐	☐	☐	☐	☐
C	☐	☐	☐	☐	☐
D	☐	☐	☐	☐	☐
E	☐	☐	☐	☐	☐

Indicate your experience with the following types of game controllers (note: only consider experience using these controllers to play games, do not include use of a keyboard/mouse for general computer tasks):

	None	Very Little	Average	High	Expert
Joystick/Flight sticks	☐	☐	☐	☐	☐
Keyboard/Mouse	☐	☐	☐	☐	☐

Single D-pad Controllers

Dual Analog Controllers

Motion Controllers

Arcade Controllers

Touchscreen Controls

Rhythm Controllers

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