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The Effect of Color on Working Memory Performance

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THE EFFECT OF COLOR ON WORKING MEMORY PERFORMANCE

by

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ABSTRACT

This paper explores the effect of color on working memory performance. Interest in Baker-Miller pink surged with the finding by Schauss (1979) that it reduced aggression in aggravated detainees. However, research behind Baker-Miller pink has been influenced by biases and methodological errors. Its effects are likely overstated. Red and blue have also been studied for their effects on creativity, approach-avoidance conflict, detail-orientation, and most importantly, stress. Further research has been conducted on the effects of relaxation on cognition, with the conclusion that increased relaxation leads to improvements in working memory performance. This paper tests the effect of color on working memory performance. Accuracy on the n-back was compared across 4 colors—pink, red, blue, and black. No significant differences in accuracy were found in any of the color conditions, though the main effect of load was significant. Future research can increase the sample size and utilize a cognitive task that is inherently stressful.

Keywords: color, Baker-Miller pink, red, blue, working memory, accuracy, n-back

DEDICATION

This is dedicated to Mayra Sanchez and Edelmira Sanchez.

ACKNOWLEDGMENTS

I would like to express my gratitude to Dr. Mark Neider and Alyssa Hess for their guidance and assistance throughout this process. I would also like to thank Drs. Mason Cash and Valerie Sims for their invaluable input and encouragement.

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INTRODUCTION

Baker-Miller pink is a shade of pink that is created with standard RGB values of 255, 145, and 175. For $35 USD, one can purchase a pair of Baker-Miller pink-tinted sunglasses for personal or experimental use. Recently, the University of Iowa came under fire when students and faculty protested against the use of the color in the Kinnick Stadium. Critics spoke out against the associations of the color to negative stereotypes about women, while former coach Hayden Fry defended its use by noting the color's calming effect (Weber, 2010).

The belief that Baker-Miller pink can elicit a calming effect on individuals exposed to the color has been investigated by researchers for the past 50 years. This effect was first discovered by Glen Wylie in 1978, and it was dubbed the kinesoid hypothesis. In his study, participants exhibited a loss in muscle strength when exposed to Baker-Miller pink during a resistance test. He derived his seminal kinesoid hypothesis from the notion that different hues may have varying effects on muscle strength (as cited in Schauss, 1979).

Baker-Miller Pink

Word of Baker-Miller pink's sedative effects would have faded into obscurity had it not been for the wave of research initiated by Schauss. Participants in Schauss' experiment were required to extend their arm forward and resist the experimenter's downward pressure to establish a subjective measure of baseline strength, while focusing on a Baker-Miller pink- or blue-tinted panel. Out of 153 participants, only two (.01 percent) were able to resist the experimenter when exposed to pink. Schauss recorded a loss in the strength of motor output in the other 151 participants. When exposed to the blue panels, their strength appeared to return to baseline (1979).

Research behind Baker-Miller pink has been limited to aggression, strength, and physiological arousal. Pellegrini, Schauss, and Birk (1980) found the same tempering effect when measuring for leg strength. In apparent consideration of the growing amount of interest in the effect of color on physiological output, Pellegrini and Schauss (1980) used a more controlled environment in their test of the kinesoid hypothesis, using a standard dynamometer to measure squeeze strength. Participants were required to focus on either a blue or pink cardboard plate while squeezing the dynamometer. A loss in muscle strength was exhibited by participants exposed to the pink plate.

The popularity of Baker-Miller pink surged in the 1970s and 1980s, when it was used to paint the walls of detention centers around the country. Schauss (1985) recorded a reduction in aggressive behavior after transgressors were confined in a pink holding cell of the U.S. Naval Academy Detention Center, noting that its application was followed by a dramatic decrease in instances of violence after 223 days. While the anecdotal evidence is relatively convincing, the results could not be replicated. Pellegrini (1981) found no significant difference in occurrences of aggressive behavior before and after the application of the color pink to a criminal detention cell, where incident reports of violent behavior were compared for the 12 months prior to and following the experimental color change. While occurrences of violent behavior decreased within the first 3 months of the change in the detention cell’s color, they increased in the 4 months following their lowest number of incident reports.

Gilliam and Unruh (1988) conducted a unique experiment that measured changes in blood pressure and heart rate, in addition to grip strength (as measured by the hand dynamometer), prior to, during, and after exposure to pink and white panels. The cognitive faculty under investigation was coding ability, measured by the Digit Symbol subtest of the Wechsler Adult Intelligence Scales-Revised. The Digit Symbol subtest was administered after 7 minutes of exposure to the first color and after 17 minutes of exposure to the second color. They offer the possibility that the effects on physiological arousal as a result of exposure to Baker-Miller pink are greatly exaggerated, as no significant differences were found in blood pressure and heart rate. Differences were found in grip strength and Digit Symbol subtest score, but these differences were not significant between white and pink.

Red and Blue

Color research is not limited to pink. Indeed, red and blue have also been studied for their effects on creativity, approach-avoidance conflict, detail-orientation, and stress. In a study by Elliot et al. (2011), color was thought to influence cognition and behavior through learned associations, where red has come to signal avoidance and blue is associated with approach. As such, people are primed to associate the color red with aversive stimuli and blue with attractive or neutral stimuli. Red was found to enhance performance on detail-oriented tasks as a result of its aversive association. Interestingly, Elliot and Aarts (2011) found that the color red (relative to gray and blue) influences motor functioning by increasing the force and velocity of motor output. In their first experiment, participants were asked to state their participation number, written in red, gray, or blue, before pinching a clasp. The maximum width of the opening was recorded. Participants in the red manipulation pinched the clasp open with greater force than those in the gray and blue manipulations. In their second experiment, participants were asked to squeeze a Biopac hand dynamometer when the word “squeeze” was presented (in black letters) on a red, blue, or gray computer background. Those in the red manipulation squeezed more rapidly, with greater maximum force and greater total force. No differences were observed between the blue and gray manipulations.

Transition, Mehta and Zhu (2009) utilized a detail-oriented task to measure memory after exposure to red. Participants were instructed to study a 36-word list for 2 minutes, and asked to recall the list after 20 minutes. The red condition recalled more correct items than the blue condition. In the realm of creative cognition, the color blue is a frequent topic of research. Blue enhances performance on creative tasks, and this effect is attributed to its association with approach motivation (Mehta & Zhu, 2009). While red enhances memory for negative words, green has the opposite effect, enhancing memory for positive words (Kuhbandner & Pekrun, 2013).

Color and Stress

Recent research points to the possibility of color exerting some influence on physiological states. Saito and Tada (2007) found evidence for color's effects on biological stress measures. In their study, color stimulated mood by alleviating psychosomatic stress. Colored photographs of natural scenery—cherry blossoms, a lake, ginkgo leaves, tree leaves, and red flowers—were presented to participants. Self-reported stress measures and concentrations of stress hormones were taken before and after the presentation of these photographs. Complared to a black and white control group, participants who were shown colored photographs exhibited decreased levels of biochemical stress markers salivary (chromogranin A and cortisol) and improved self-reported mood levels.

Stress and Cognition

Schauss (year) argued that Baker-Miller pink's relaxing effects influenced behavior and physiological strength. In the present day, relaxation has been studied for its cognitive benefits, particularly to working memory. In testing for working memory performance, Hudetz, Hudetz, and Klayman (2000) found an improvement in performance on the WAIS-III Letter Number Sequencing Test after a guided imagery relaxation exercise. They did not find this effect after exposure to popular music or in the control group. Hudetz, Hudetz, and Reddy (2004) found that the relaxation elicited by 16 minutes of guided imagery reduced anxiety and EEG activity, which in turn had a positive effect on working memory. Considering the potential of relaxation in improving working memory, and Baker-Miller pink's purported relaxing effects, color may exert a significant effect on cognitive performance. Simply put, if color has an effect of stress, and if stress has an effect on cognition, then color could have an effect on cognition. A color that elicits relaxation may improve cognitive performance, while a color that elicits stress may serve as a detriment.

Influence of Color on Working Memory Performance

Baker-Miller pink's effects have not been documented in the area of cognition with nearly as much tenacity as physiological output. I expect to find a correlation between color and cognitive performance. If Baker-Miller pink has a tempering effect on human physiological stress, then according to Hudetz et al. (2000, 2004), the color may have a significant positive effect on cognitive performance. Pink's effect on working memory should also parallel that of blue, which research has shown may have a relaxing effect on individuals. On this note, the color red may have a negative effect on cognitive performance, due to its propensity to elicit physiological arousal.

While the aforementioned studies analyzed color in a host of different methodologies, varying from a random image to a laboratory background, it has yet to be seen whether intentionally attending to the color itself will have an effect on performance. The studies did not require participants to consciously attend to the color, barring those that required participants to concentrate on colored panels. I manipulated the stimuli, using the n-back to measure working memory performance. In the present study, target letters in an n-back task were manipulated into either Baker-Miller pink, blue, red, or black, in order to more appropriately test the effect of color on working memory performance.

With the increase in load, there will be a decrease in working memory accuracy. With this in mind, I predict that red will be positively correlated with greater total working memory accuracy. Blue will be positively correlated with working memory accuracy for the 3-back, while red will be negatively correlated. There will be no effect of either pink or black on working memory accuracy.

METHOD

Participants

The 28 participants in this study were students at the University of Central Florida seeking credit for a psychology course through the SONA system. The sample consisted of 21 females and 7 males. The average age of the sample was 19.54. The demographics were reported as follows: 3.57% Native Hawaiian or other Pacific Islander, 3.57% Asian, 10.71% black or African American, 60.71% white/Caucasian, and 21.43% other. Informed consent was obtained from all participants before participation.

Apparatus

Participants were run on a basic desktop PC running Windows. The n-back was presented on a DELL1707FP monitor with a resolution of 1280 x 1024 pixels. Basic keyboards were used to respond. An n-back task developed using E-Prime was used to measure working memory performance. Elliot and Aarts (2011) have suggested that future studies must control for hue, lightness, and chroma, as imprecise color manipulations may have confounded results in previous color research. In using the standard RGB color value system and maintaining consistent luminance on the computer screen, these three dimensions were controlled.

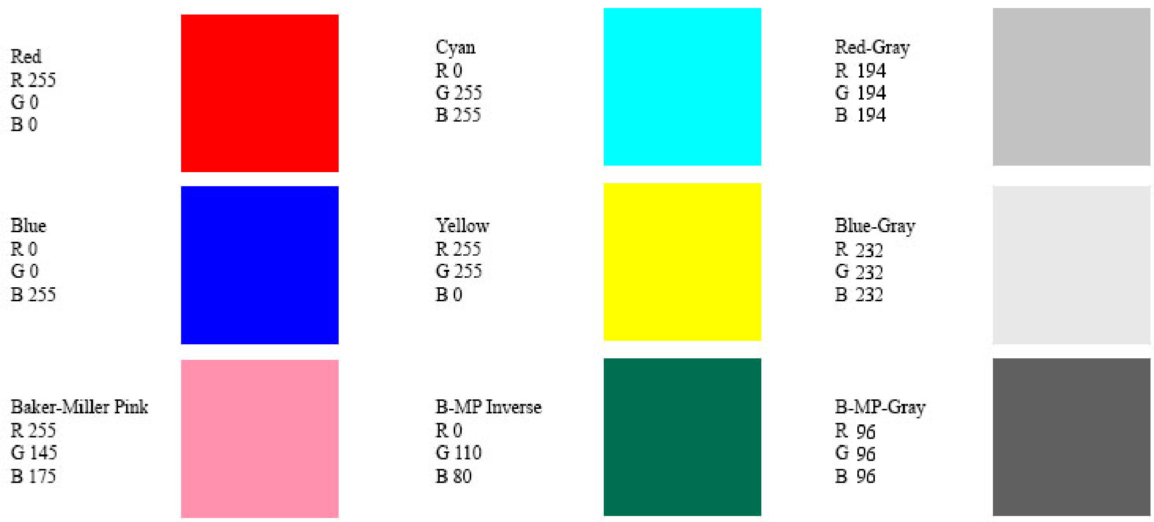

Figure 1. Color manipulations and corresponding RGB values.

Design

This was a 4 x 4 mixed factorial design. Color and n-back were the independent variables. Color was a between-subjects variable with four conditions--pink, red, blue, and black. Number back was a within-subjects variable with 4 conditions: 0-back, 1-back, 2-back, and 3-back. Accuracy was the sole dependent variable. Number back is required to be a within subjects variable. It is necessary to run a participant from the 0-back to the 3-back. While color could have been a within-subjects variable, it was important to expose a participant to only one color at one time. Otherwise, it would risk the influence of carryover effects from one color to another.

The n-back (Kirchner, 1958) was chosen to measure working memory performance. The unique RGB values for Baker-Miller pink, red, and blue were used. Each color's corresponding gray was found using MATLAB's rgb2gray function, which eliminated hue and saturation while preserving brightness. Letter color was set using the Forecolor option in E-Prime. Likewise, background color was set using the Backcolor option. The letters were presented against a background shaded in the letter color's corresponding gray. Before each task, the participants were given a set of instructions and a practice session, neither of which used the manipulated colors.

Previous research is unclear as to how the color should be presented to the participant. While some researchers preferred the use of colored panels, others decided to expose the participant to colored photographs and colored backgrounds. The letter was designated as the only colored portion to reduce the possibility of a negative afterimage.

Procedure

Participants gave their informed consent and answered a series of basic demographic questions upon entering the lab. Those under the age of 18 or who did not sign the consent form were unable to participate. Near- and far-vision were tested with Snellen charts, and color blindness was tested with Ishihara plates. Any color-blind participants were excluded from the study. After the participant had their vision screened, they were seated at an available computer and run through the n-back test (from the 0-back to the 3-back) in one color condition (either pink, red, blue, or black). Before each n-back, the participant was given a set of detailed instructions and a practice session, which they were free to repeat. During the 0-back, the participant saw letters appear in consecutive order in the center of the screen. The participant was instructed to press "target" (the numerical "1" button) when an "x" appeared on the screen. They pressed "not a target" (the numerical "2" button) for any other letter. During the 1-back, the participants saw another stream of letters, and they pressed "target" when the letter before a given letter matched the one presented before it. For the 2-back, a given letter must match that presented two letters before it. Finally, for the 3-back, a given letter must match that presented three letters before it. Every level of the number-back had three trials, with a total of thirty possible hits (or misses) and sixty possible correct rejections (or false alarms). In each trial, there were ten possible targets and twenty non-targets. The number of hits, misses, correct rejections, and false alarms were recorded. Hits and correct rejections were added, and the sum was divided by the total possible number of hits and correct rejections (ninety) to find the accuracy rate.

After completing the experiment, participants were debriefed on the purpose of the experiment and thanked for their participation. The session lasted no more than forty-five minutes.

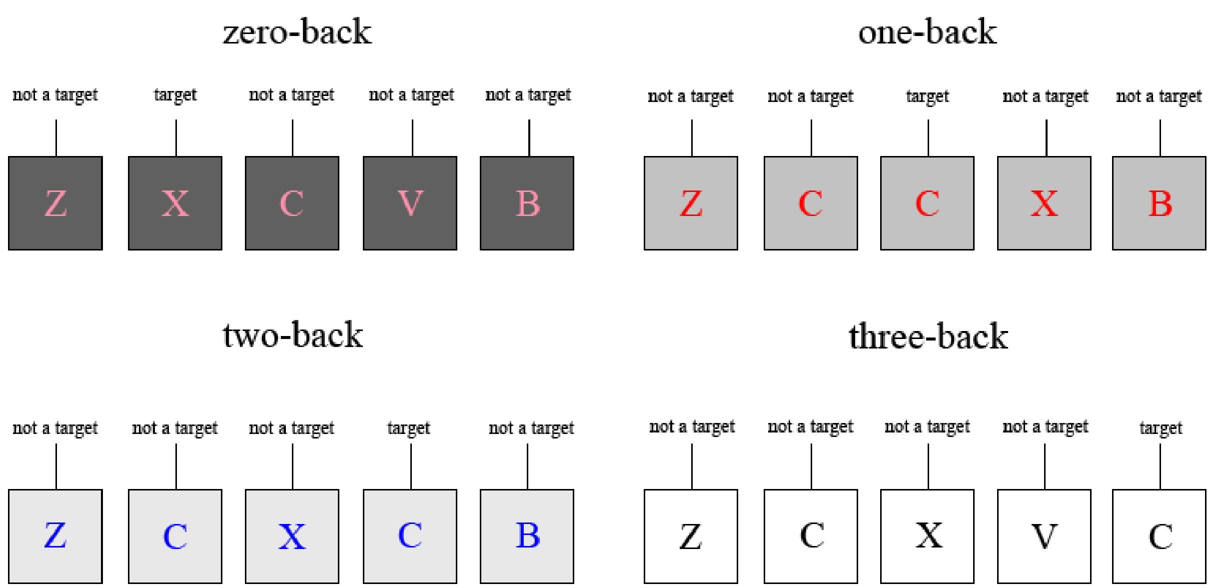

Figure 2. Examples of 4 color and n-back conditions.

RESULTS

A univariate analysis of variance was conducted to compare the effect of color on working memory performance across multiple levels of the n-back where the target stimulus was shown in pink, red, blue, or black. The independent variables were color and n-back. The dependent measure was accuracy, which was found by dividing the sum of the participant's reported hits and correct rejections by the sum of the total possible number of hits and correct rejections. The alpha value was set to .05.

There was no significant effect of color on accuracy ($F(3,9) = 0.31$, $p = 0.82$). There was a significant main effect of n-back on accuracy ($F(3,9) = 15.58$, $p < .05$),. There was no significant interaction between color and n-back ($F(9,9) = 0.17$, $p = 1.00$).

There was a significant difference in accuracy between the 0-back (*M* = 98.26, *SE* = 1.32) and the 2-back (*M* = 93.18, *SE* = 1.32; *MD* = 5.08, *SE* = 1.87; $p < .05$), the 0-back and the 3-back (*M* = 86.07, *SE* = 1.32; *MD* = 12.18, *SE* = 1.87; $p < .05$), the 1-back (*M* = 95.44, *SE* = 1.32) and the 3-back (*MD* = 9.37, *SE* = 1.87; $p < .05$), and the 2-back and the 3-back (*MD* = 7.10, *SE* = 1.87; $p < .05$).

Table 1. Accuracy for color and n-back.

	Number back				
	0	*1*	*2*	*3*	*Total*
Pink	97.30 (2.79)	95.87 (2.38)	93.49 (4.23)	86.98 (10.67)	93.41 (6.96)
Red	99.21 (0.54)	97.78 (1.70)	93.016 (5.51)	86.67 (6.51)	94.17 (6.46)
Blue	98.89 (0.91)	93.97 (6.66)	93.65 (9.00)	85.08 (15.65)	92.90 (10.39)
Black	97.62 (2.17)	94.13 (5.80)	92.54 (9.07)	85.56 (8.21)	92.46 (7.86)
Total	98.25 (1.92)	95.44 (4.66)	93.17 (6.87)	86.07 (10.23)	93.23 (7.98)

Values in parentheses indicate standard deviation.

DISCUSSION

The research question under investigation was whether color would have a significant effect on working memory performance, as measured by accuracy of response to the zero-back, one-back, two-back, and three-back. I predicted that participants would perform with the highest accuracy when exposed to red. As such, there would be a significant difference between the accuracy of participants' responses in the red condition as compared to all other colors. There would be no marked differences in accuracy between all other colors, in that participants would respond with similar levels of accuracy to pink, blue, and black. Additionally, participants in the blue condition would outperform all colors in the three-back, while those in the red condition would perform with the lowest level of accuracy.

In this study, color has no effect on relaxation and performance. Both the main effect for color and the color by n-back interaction were not significant. However, the main effect of n-back load was significant. From this, we conclude that color has no effect on accuracy. Specifically, red and blue are no better than other colors in affecting working memory performance.

There must be another variable at work in the findings presented by Schauss (1979) and Pellegrini et al. (1980). This assumption stems from research by Smith, Bell, and Fusco (1986), who measured motor output using a hand dynamometer after exposure to 8 different colored panels--blue, light blue, green, brown, yellow, orange, pink, and red. After 60 seconds of exposure to a colored panel, participants were instructed to squeeze on a hand dynamometer at full force. However, the participants were also deceived into believing that blue or pink either decreases or increases muscle strength. Curiously, male participants who were told that pink would increase their muscle strength had higher grip strength than those who were told pink would decrease it. For women, the opposite effect was observed. Because of the results found by Smith, Bell and Fusco, I am prompted to believe the possibility that the results found by Schauss were due to suggestion. Demand characteristics may have influenced participants to respond a certain way.

Our culture and society place weight on the meaning of certain colors. While we can argue that the color red is certainly more salient and easily remembered, it is also a color that draws associations to concepts such as attention, violence, and passion. Moller, Elliot, and Maier (2009) tested the effect of red and green on failure-related and success-related words. They brought up the importance of the valence attached to these colors, where red had a negative valence. The color red was found to be associated with failure. It is common to find red emergency controls. Courtney (1986) found that Americans typically associate red with the concepts “go,” “stop,” “danger,” and “hot” (Helander, 2006, p. 104-5). Within industrial and military environments, red indicates an alert, signaling an emergency, danger, or malfunction (p. 320). It is recommended that emergency controls are designed in red, to allow for fast reaction to error (p. 108). Though red is within the same spectrum as pink, the meaning behind these colors is dramatically different. Currently, pink is associated with femininity, while blue is considered a more masculine color.

All in all, relevant research on color and stress is scant, so there was little to base the hypotheses on. I did not anticipate participants in the pink condition to perform with any significant differences. Schauss’ methodology is questionable and ultimately flawed (Schauss, 1979). Strength measures taken during the kinesoid experiment were subjective, and it was only later that a dynamometer was used (Pellegrini, 1980; Pellegrini & Schauss, 1980). In a classic example of the Hawthorne effect, it's possible that the change to the environment (and the attention given to the strip search room) prompted detainees to behave in a manner consistent with the researchers' expectations. Additionally, the arresting officers or Sheriff's Deputies could have acted in a manner that would diminish the possibility of an aggressive encounter. The sedative effects observed by Pellegrini, Schauss, and Miller (1980) can thus be explained not by the presence of Baker-Miller pink, but by an observer-expectancy effect.

Hudetz et al. (2004) offers convincing justification for detriments in working memory attributed to stress, and my entire argument was centered on their findings. The present study fails to isolate the effect of stress on working memory. Essentially, there was no way of knowing whether the colors increased or decreased stress at all. It is also possible that the task simply was not stressful enough. This may explain why we did not observe the dramatic differences in accuracy between red and blue that were predicted for the three-back. In addition, stress itself may not affect performance on the n-back. It is entirely possible that the n-back is simply fatiguing, not stressful.

This research is limited by its method and sample size. As this experiment had a sample size of 28 participants, a greater sample size would help obtain a more diverse set of responses. Future research could test for working memory differences using other working memory tasks. If using the n-back, future research could increase the load presented. This could elicit more dramatic and observable differences between the colors. I would suggest that future experiments utilize a task that is stressful (rather than fatiguing). The WAIS-III Letter Number Sequencing Test was chosen by Hudetz et al. (2000, 2004) because it was an inherently stressful cognitive task, a fact that was overlooked in the conception of the present study. In addition, future research may investigate both the effect of suggestion and the stereotype threat prompted by exposure to blue or pink on performance. Regrettably, the sample size of the present study was not large enough (and hence, the distribution of males to females) to analyze the data with gender in mind.

APPENDIX

IRB APPROVAL FORM

University of Central Florida Institutional Review Board
Office of Research & Commercialization
12201 Research Parkway, Suite 501
Orlando, Florida 32826-3246
Telephone: 407-823-2901 or 407-882-2276
www.research.ucf.edu/compliance/irb.html

Approval of Human Research

From: **UCF Institutional Review Board #1**
FWA00000351, IRB00001138

To: **Mark Neider** and Co-PIs: **Alyssa S. Hess, Michelle Galvez**

Date: **February 20, 2015**

Dear Researcher:

On 2/20/2015, the IRB approved the following human participant research until 02/19/2016 inclusive:

Type of Review:	UCF Initial Review Submission Form
Project Title:	Analyzing Working Memory Performance
Investigator:	Mark Neider
IRB Number:	SBE-15-10953
Funding Agency:	
Grant Title:	
Research ID:	N/A

The scientific merit of the research was considered during the IRB review. The Continuing Review Application must be submitted 30days prior to the expiration date for studies that were previously expedited, and 60 days prior to the expiration date for research that was previously reviewed at a convened meeting. Do not make changes to the study (i.e., protocol, methodology, consent form, personnel, site, etc.) before obtaining IRB approval. A Modification Form **cannot** be used to extend the approval period of a study. All forms may be completed and submitted online at https://iris.research.ucf.edu .

If continuing review approval is not granted before the expiration date of 02/19/2016, approval of this research expires on that date. When you have completed your research, please submit a Study Closure request in iRIS so that IRB records will be accurate.

Use of the approved, stamped consent document(s) is required. The new form supersedes all previous versions, which are now invalid for further use. Only approved investigators (or other approved key study personnel) may solicit consent for research participation. Participants or their representatives must receive a copy of the consent form(s).

All data, including signed consent forms if applicable, must be retained and secured per protocol for a minimum of five years (six if HIPAA applies) past the completion of this research. Any links to the identification of participants should be maintained and secured per protocol. Additional requirements may be imposed by your funding agency, your department, or other entities. Access to data is limited to authorized individuals listed as key study personnel.

In the conduct of this research, you are responsible to follow the requirements of the Investigator Manual.

On behalf of Sophia Dziegielewski, Ph.D., L.C.S.W., UCF IRB Chair, this letter is signed by:

Joanne Muratori

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Signature applied by Joanne Muratori on 02/20/2015 12:32:20 PM EST

IRB manager

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