Enhancing exercise induced feed forward response through exposure to related and unrelated visual stimulus

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Key Points Summary

- Exercise Induced Feed Forward response is a naturally occurring phenomena observed in healthy human beings
- Visual stimulation associated with amplifying the sympathetic human response has been observed in a wide variety of human studies
- Our results indicate the possibility of a feed forward amplification due to exercise related visual stimulation in participants previous to exercise
- No significant conclusion could be drawn from our data but with improved experimental protocol and further research promising conclusive results could be obtained

Abstract:

The physiological feed forward response is well documented in both humans and other mammals. It is an unconscious phenomenon by which the body prepares itself for activity spurred merely by an anticipatory stimulus. In humans, the feed forward response has been found to affect digestion, physical activity, and thermal regulation. In a study involving 23 healthy human adults, participants were exposed to exercise specific visual stimulus in an attempt to document possible feed forward amplification prior to moderate physical activity. Though the study failed to reach any significant conclusions regarding feed forward amplification, it has provided valuable information for improvement in related future research.

Introduction

The hypothesis that had been constructed in the following study involves the viewing of a strenuous exercise related video and its modulating effects on the body's existing feed-forward response. While there has been no documented experiment that has tried to investigate this effect through such a setup, there have been studies that have correlated consumption of media with increased physiological activity. An example of such an experiment included exploring physiological effects of playing a video game depicting vigorous physical activity, i.e. a fighting game (Wang and Perry, 2006). The experimenters found that video games that depict vigorous physical activity positively correlate with physiological rates, such as heart and respiration rate. We expect to find similar results when substituting an exercise related video for the video game scenario and hope to provide possible useful applications for the observed phenomenon.

The physiological feed forward response is well documented in both humans and other mammals. It is a fascinating phenomenon by which the body prepares itself for activity spurred merely by an anticipatory stimulus. The feed forward response has been found to affect digestion, physical activity, and thermal regulation. It is a response that often is unconscious and brought about regardless of intent of the individual. Our study aims to document this effect as it relates to exercise in healthy male and female human adults. We aim to observe not only the feed forward phenomenon, but also to examine whether this response can been augmented from baseline levels through visual stimulus. Evidence of augmentation could have significant application in sports training, competition and overall physical performance in any activity related environment.

The feed forward effect has been documented in a study conducted by Wang and Morgan in 1992. The experimenters wanted to study the effects of mental imagery on physiological responses. The experimenters took measures at three different times; a baseline measure, a measure after imagery, and a measure after actually exercise. Initially, subjects were asked to sit quietly for 3 minutes while various measurements were taken. Then, subjects were led by experimenters to imagine themselves doing curls of a dumbbell. Measurements were taken directly afterward. Subjects were given a dumbbell and were told to do as many curls as they could, with measurements following. Wang and Morgan found that systolic blood pressure measurements taken after imagery were significantly higher than baseline, and that systolic blood pressure was similar to that taken after actual exercise. Similarly, respiration rate and volume of breath were found to be significantly higher after imagery than baseline (and significantly lower than actual exercise). The data suggests that when individuals imagine themselves doing exercise, there will be an elevated physiological response and this response will mimic that of actual exercise, but will not be as intense as actual exercise.

Another experiment conducted aimed to identify whether the increased physiological response in imagery was actually due to motor anticipation (feed forward), or simply due to strenuous mental activity (Oishi et al., 2000). To test this, the study recruited eight professional speed skaters who were trained to mentally imagine themselves speed skating at their top speeds. In addition, these athletes were given difficult math problems to complete. The rationale was that if the increased physiological response was due to strenuous mental activity and not motor anticipation (feed-forward), then there should be no difference between the elevated physiological rates of speed skating imagery and during the solving of difficult math problems. A baseline measure of heart rate and respiration were taken before the tasks. Then, measurements were retaken directly after imagery (or after the difficult math set was completed). In comparison to baseline measurements, data suggested that both the process of imagination and math significantly increased heart rate (Oishi et al., 2000). However, as hypothesized, heart rate values were also significantly higher than heart rate measured after math problems. In addition, respiration rates were significantly higher than baseline as well. However, there was no statistical difference of respiration rates between imagery and math. It was noted that in the imagery condition, respiration rates of subjects were extremely irregular, which was similar to actual exercise, and that it was this variability that prevented them from finding statistical significance. Overall, the experimenters concluded two things, both imagery and difficult math raised physiological measures of heart rate and respiration rates, however, when one is imagining exercise, these rises are either higher than non-imagery mental activity, or the physiological response more closely mimics the actual physical activity. Therefore, the experimenters concluded that imagery of physical exercise does indeed activate a motor anticipation (feed forward) response, and that these responses mimic actual exercise.

Materials and Methods

Ethical Approval:

Participants were informed of experimental procedure and were provided with a written consent form (approved by the Physiology 435 Ethical Review Board) prior to participation (see attached figure 2).

Baseline measurements including blood pressure (BP), heart rate (HR), and respiration rate were taken from twenty-three participants (12 males, 11 females) who took part in a one-day experiment. Experimenters read from a script to ensure consistency in the instructions (Figure 1). Participants were asked to be prepared to engage in moderate levels of exercise and were informed of the measurements to be taken afterwards. Participants ranged in age from twenty to twenty nine years (χ=22, SD=2.090) and reported to be in good health. Once a participant arrived and is notified of the procedure, a baseline measurement was taken. Pulse pressure (PP= systolic pressure-diastolic pressure) and mean arterial blood pressure (MABP = diastolic pressure + 1/3 pulse pressure) and were calculated.

The participant then viewed a short (90 second) video that consisted of either a young adult vigorously exercising or a generic "relaxation" video, involving nature scenes and waterfalls (Figure 3) Videos were obtained online from www.*youtube*.com. Seven males were randomized into group A and five males into group B. Five females were randomized to group A and seven females into group B. The videos were screened on a thirteen inch computer monitor at a comfortable listening volume. To ensure for greater subject concentration and to filter out any extraneous sound, subjects used inner-ear headphones. Both volume and video size were kept constant for each participant. After viewing the provided media, a second set of measurements was taken including HR, BP, and respiration rate.

After the second set of measurements, each participant took part in a three-minute session of moderate physical activity. Participants pedaled a Schwinn Bio-Dyne resistance-based stationary bike and were monitored to ensure that an effort necessary to sustain an elevated heart rate was maintained. Subjects were told to maintain a perceived effort of "six out of ten". In an attempt to disguise the motive of the experiment, an arbitrary third set of measurements was taken after the exercise session. In theory, participants should have been led to believe that the third and final set of measurements held the most significance. See Figure 4 for display of protocol.

Each participant took part in one experimental sessions conducted in the manner described above. Eleven participants viewed the exercise video during their session, and twelve participants viewed the non-exercise video during their session.

Heart rate measurements were taken via a NONIN Pulse Oximeter/Carbon Dioxide Detector (Model no. 9843). The NONIN Pulse Oximeter determines heart rate based on a signal taken by a sensor attached to the participant's finger. Blood pressure was taken with an Accumax Labtron systolic/diastolic blood pressure cuff. Finally, respiration rate was detected and recorded using a BIOPAC respiratory transducer. The BIOPAC respiratory transducer works by using a force sensitive resistor attached to a chest strap that measures the participant's breath cycle, equating the lowest point of force and highest point of force to minimum inhalation and maximum exhalation respectively. The signal is then converted based on the number of breath cycles per time unit (breaths per minute, BPM) and is displayed and processed through BIOPAC computer software. To ensure uniformity, participants were asked to wear only one layer of clothing, which varied from a standard t-shirt to a light sweater in some cases.

To avoid inconsistencies, each set of measurements was taken in the same order; respiration rate was taken simultaneously with heart rate, while blood pressure was measured no longer than 30 seconds after the end of the appropriate media. To minimize confounding variables such as distraction or social exercise-related nervousness, the experiment was conducted in a secluded area of our lab space.

Results:

No measurements were found to be statistically significant. However, the general trend of the data correlated with expectations, as post-video measurements generally increased from baseline measurements for both groups. Chart 1 describes all means and standard deviations, for group A and B respectively, for each individual measurement.

N=23 (Males=12, Females=11)	Group A N=11 (M=7, F=4)		Group B N=12 (M=5, F=7)	
	Baseline	Post-video Measurements	Baseline	Post-video Measurements
Heart Rate (Beats/minute)	70.7 (12.2)	74.1 (13.7)	65.9 (8.79)	71.1 (9.03)
Systolic Blood Pressure (mmHG)	124.1 (4.34)	122.8 (3.31)	124.9 (6.48)	121.2 (5.82)
Diastolic Blood Pressure (mmHG)	63.1 (15.9)	65.2 10.5)	69.8 (9.97)	69.6 (8.37)
Mean Arteriole Blood Pressure (mmHG)	83.4 (3.8)	84.34 (2.30)	88.17 (4.5)	86.76 (1.85)
Pulse Pressure (mmHG)	61(4.37)	57.63 (2.76)	55.05 (2.21)	51.58 (2.51)
Respiratory Rate (breaths/minute)	18.9 (6.42)	22.1 (7.63)	14.6 (4.81)	17.4 (6.25)

Table 1. Comparison Between Group A and B: Baseline and Post-video Measurements

Mean (Standard deviation) Group A watched exercise video; Group B watched relaxation video

8 Single-Variate ANOVAs were run for each baseline measurement compared to post video measurement, in Group A and Group B respectively. [e.g. the ANOVA run for Group A heart rate baseline compared to post-video heart rate was found to be statistically insignificant ($p=.54$)]. It was hypothesized that post-video measurements would be significantly higher than baseline in both groups. All 8 statistical values were found to be insignificant, and are listed below in chart 2. These values suggest that there was no physiological difference from baseline to post-video measurements, suggesting that the manipulation for the feed-forward response was ineffectual.

N=23 (Males=12, Females=11)	Group A N=11 (M=7, F=4)		Group B N=12 (M=5, F=7)	
	P-value	Frequency	P-value	Frequency
Heart Rate (beats/minute)	0.54	0.38	0.16	2.01
Systolic Blood Pressure (mmHG)	0.45	0.59	0.15	2.21
Diastolic Blood Pressure (mmHG)	0.71	0.13	0.95	0.004
Mean Arteriole Blood Pressure (mmHG)	.81	.05	.21	.64
Pulse Pressure (mmHG)	.52	.42	.30	1.09
Respiratory Rate (breaths/minute)	0.30	1.18	0.22	1.54

Table 2. Correlations Between Baseline Mean and Post-video Mean for Group A and Group B

Additionally, 4 single variate ANOVAs were run between the post-video measurements of group A vs. group B for each variable measurement. It was hypothesized that each variable of Group A would be significantly higher than Group B. Table 3 details the results. None of the comparisons reached a level of statistical significance, though RR had a p-value of 0.12. The data suggests that there was no difference between the videos shown and the physiological feed-forward effect.

Variables	P-value	Frequency
Heart Rate (beats/minute)	0.52	0.41
Systolic Blood Pressure (mmHG)	0.41	0.67
Diastolic Blood Pressure (mmHG)	0.27	1.24
Respiratory Rate (breaths/minute)	0.12	2.59

Table 3. Significance Between Group A and B: Post-Video Measurements

Finally, individual measurements were compared between baseline and post-video measurements. This was done by subtracting baseline measurements from post-video measurements of each individual. This was then analyzed via ANOVA between group A vs. Group B. There was no significant difference between any of the variables from in Group A vs. Group B. Our data suggests that there were no significant individual differences between groups.

Variables	P-value	Frequency
Heart Rate (beats/minute)	0.49	0.48
Mean Arteriole Blood Pressure (mmHG)	0.62	0.25
Pulse Pressure (mmHG)	0.20	1.70
Respiratory Rate (breaths/minute)	0.78	0.07

Table 4. Individual differences in Group A Vs. Group B

Discussion

Results reveal no statistically significant difference between the measurements of baseline and the post-video group. However, we cannot draw the conclusion that the imagery stimulation doesn't work on the feed-forward system or there is no feed-forward response between exercise video and vital signs such as heart rate, blood pressure and respiratory rate. Heart rate and respiratory rate in both post-video groups have increased in comparison to the baseline values. It may be possible that the feed-forward response does affect the circulation and respiratory system through exercise and relaxation videos, but we failed to collect the persuasive data that has significant difference compared to the baseline.

A justification for our findings could be that the exercise video might not have been intensive enough to trigger the sympathetic nervous system and cause a significant increase in heart rate, respiratory rate, or blood pressure. The video chosen for participants depicted an athlete running for 90 seconds on a treadmill. It is possible that participants might not have been interested in the provided media and therefore failed to make a personal connection. Furthermore, whether the video will increase the physiological signs of the body also depends on whether the participants themselves are interested in exercise or not. Participants who do not like running might not have any response to the video they were watching. In either of these situations, data could arise that speaks against our hypothesis. Even if the video was appropriate, in terms of level of exercise portrayed, to trigger the feed-forward response of each participant, it would be difficult to estimate exactly how much it will increase the heart rate, blood pressure and respiratory rate, and how long the change will last. Our post-video measurements were taken within 30 seconds of the video's end, and any changes in vitals might have been so minimal that values returned to baseline in as little as 10 seconds after viewing the video. In this case, we might have failed to note this difference from the baseline. To better support our hypothesis in future studies, we would need to choose participants who are interested in sports, specifically those sports which correlate to the provided media. The level of exercise subjects engage in on a daily basis and frequency of exercise should also be noted. In addition, taking measurements during the subjects' entire viewing of the video would also help to investigate the point at which the body experiences the biggest change during the experiment.

Another reason for the unexpected results may be lack of consideration of variants during the experiment, which may have affected the results. Although each measurement was taken in the same classroom, and external environment was relatively maintained, we did not consider the sex of each participant. While more than half of our participants were female, it could be possible that the feed-forward system is more sensitive in males compared to that in females. Maintaining an equal balance of male and female participants might reduce the diversity between pre- and post-video measurements. Another factor that undermines the results could be the possible neglect of participants' age. Although most of our participants were students in an upper level college physiology class and contained relatively small age deviation, there is the possibility that the feed-forward response may depend on age. To refine our experiments, we should take into consideration the participants' sex and age, which may lead to data of greater statistical significance.

In addition to such variants, the manner in which the experiments were conducted may have led to errors in the results. The sample size was quite small, and subjects were often unaware of the following exercise portion of the trials, whether it was due to lack of emphasis on this portion or subject had simply forgotten and was not thinking about the exercise they were about to perform. Baseline measurements may have been high to begin with due to participants' initial excitement, thus causing little or no change in measurements from baseline to post-video data. Often, we could not control the environment each participant was exposed to right before experimentation. Many subjects who were not part of our physiology course came from outside environments in which possible excitatory stimulus may have been present. We also may have failed to ask each participant to take a moment to relax. By doing so, we could possibly have achieved a more accurate baseline set of measurements. Furthermore, we often noticed an elevation in many subjects' heart rate and respiratory rate during the attachment of measurement devices. Most participants had never taken part in such an experiment and the constricting and awkward nature of the respiratory belt and blood pressure cuff could have elevated baseline measurements.

Understanding the link between the feed forward response and environmental conditions may prove useful for a variety of reasons. Further knowledge of the mechanisms behind such a response would allow for self-controlled manipulation of the physiological response, allowing an enhanced outcome depending on what's desired. For example, during exercise or any form of physical training, knowing which particular events induce the feed-forward response would allow the individual to accelerate heart rate prematurely prior to actual exercise, which proves beneficial to physical training in general. Further research should be done to further explore the feed-forward response and its underlying mechanisms, so that we may be able to better utilize its strengths and benefits.

References

Cheng, Teddy M., and Andrey V. Savkin. "Nonlinearmodeling and Control of Human Heart Rate Response during Exercise with Various Work Load Intensities." *IEEE Transactions on Biomedical Engineering* 55.11 (2008): 2499. Print.

Kazuo Oishi, Tatsuya Kasai and Takashi Maeshima “Autonomic Response Specificity during Motor Imagery”. Journal of PHYSIOLOGICAL ANTHROPOLOGY and Applied Human Science Vol. 19; 255-261 (2000)

Kjaer, M., F. Pott, P. Tornoe, and N. H. Secher. "Heart Rate during Exercise with Leg Vascular Occusion in Spinal Cord-injury Humans." *Journal of Applied Physiology* 86 (1999): 806-11. Print.

Legramante, Jacopo M., Gianfranco Raimondi, and Michele Massaro. "Investigating Feed-forward Neural Regulation of Circulation from Analysis of Spontaneous Arterial Pressure and Heart Rate Fluctuations." *Circulation-Journal of the Americal Heart Association* 99 (1999): 1760-766. Print.

Wang, Xuewen, and Arlette C. Perry. "Metabolic and Physiologic Responses to Video Game Play in 7- to 10-Year-Old Boys." *Archives of Pediatrics Adolescent Medicine* 160.4 (2006): 411-5. Print.

Wang, Youde, and William P. Morgan. "The Effect of Imagery Perspectives on the Psychophysiological Responses to Imagined Exercise." *Behavioural brain research* 52.2 (1992): 167-74. Print.

William JW, et al. “New insights into central cardiovascular control during exercise in humans: a central command update.” *Exp. Physiol* 2006; 9: 51-58.

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Authors' Translational Perspective:

With further, improved research, findings related to an amplification of the feed forward response could have wide ranging applications in a number of practical fields. The potential to improve human performance through an increase in physiological preparedness preceding physical exertion could be applied to athletics, the military, or any other physically demanding activity where opportunity to amplify the feed forward response is available. Further, with the ever increasing budgets and profits acquired by athletic departments across the country and the massive amount of capital involved in professional sports, further research in this area seems inevitable.

Figures and legends

Figure 1: Script

Experimenter/Experimentress:

Bienvenidos! Welcome to our experiment. Please read over and sign our consent form. Today you will be taking part in an EXERCISE-based research study. Two additional sets of measurements will be taken and you will be required to participate in three minutes of PHYSICAL ACTIVITY on our "*totally sweet*" vintage exercise bike.

The procedure will be as follows:

You will now watch a 90 second video. Afterwards, a second set of measurements will be made and the EXERCISE portion of our study will commence. Finally, after concluding with the EXERCISE segment of our study we will make the final and most important set of measurements.

Thank you for participating; you have been a credit to the human race. Your willingness and ambition has put science back on top. GO USA!

Figure 2: Consent form

The not so Generic Consent Form

On this date of _________________

I, ____, hereby allow the students of Physiology 435 to utilize the data collected during this experiment no matter how bizarre, unnatural, or downright confusing their motives may seem.

I understand that the experimenters plan to analyze and share this data, possibly with the intent of achieving great wealth and/or fame. As a participant I am granted complete anonymity and guaranteed no financial reciprocity of any kind for my involvement.

I understand that I am required to partake in two sessions (over the course of two days) of mild exercise in this two part experiment. The exercise required includes one to two minutes of mild cardiovascular activity.

I acknowledge and agree that I am healthy enough and physically fit enough to complete these measurements/experiments without undo physical harm to myself, the experimenters, or the general public at large.

Signature_____________________________

Figure 3: Video internet links

Exercise: http://www.youtube.com/watch?v=6Chg_5NpQJo

Non-exercise: http://www.youtube.com/watch?v=44YGF9fmEEo

Figure 4: Protocol