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THE EFFECTS OF PHYSICAL EFFORT ON AROUSAL

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ABSTRACT

Cognitive and physical activities often interact with arousal in our daily lives. As an example, a reaction of fear triggered by visual identification of a dangerous object or situation may elicit a stress response that prepares the body to fight or flee. The proposed study therefore considers arousal to stimuli in relation to motor actions. Specifically, it investigates whether physical exertion affects arousal. Physical exertion is experimentally induced with a hand grip task in which participants squeeze a hand dynamometer with exerted grip force proportional to their physical strength. Arousal level is assessed with a pictorial assessment task in which participants report the arousal level of images on a 9-point scale. It is hypothesized that arousal ratings with the concurrent hand grip task will increase with exerted handgrip force. This study is significant because it will examine whether arousal is connected to physical action in our daily lives.

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INTRODUCTION

The interactions between, physical actions, cognitive processes, and arousal is a complex and relevant area of study. Physical arousal is related to cognition, as we commonly see in daily life(Park et al. 2021; Mehta, 2016; Rosenbaum, 2017). As an example, parents may carry a baby and pick out an outfit at the same time. This scenario exemplifies how physical actions and cognitive processes may coexist. Given the importance of this relationship, Park and his team considered how concurrent physical action affects cognitive processes(2021).

In their study, they measured physical arousal using hand grip exertion, with participants using either 5 or 40 percent of their maximum physical strength(measured as MVC), with a hand dynamometer. The participants were then instructed to do a cognitive search task, which was a shape singleton task that had a distractor element. It was a dual-task experiment, as a handgrip task and a singleton visual search task were done at the same time (Park et al. 2021, Theeuwes, 1992).

Physical action is known to induce emotional arousal, especially at a moderate level (instead of high or low levels) (Park et al. 2021; Davranche et al., 2006; Droit-Volet & Berthon, 2017; Yerkes & Dodson, 1908). Hence, the higher condition for physical exertion was 40 percent muscle contraction.

Also, the more different the grip force for participants in the low and high physical load conditions, the more different the effect of the color singleton distractor in the conditions(Park et al. 2021). The effect of the distractor was different in that it had less of an effect on the high physical load condition, leading to a better performance on the search task overall. This further highlights that physical arousal may have a relationship to cognitive processes. This relationship is seen in daily life, and it has also been examined and demonstrated in research.

Zhang (2022) investigated the effects of induced negative arousal on working memory representations. He and his team look at arousal, specifically when an emotional experience is negative in valence (e.g., Kensinger, 2007; Kensinger et al., 2007; Xie & Zhang, 2017c, but see Talarico, LaBar, & Rubin, 2004). Negative arousal was induced through a change detection task, in which 120 undergraduate participants heard 6-second IADS audio clips that led to negative or neutral arousal levels. Under negative arousal, more items were encoded in working memory with a small effect size (d=0.20). Negative arousal was associated with working memory consolidation, with a small effect size. Individual differences, including those with more fear from the clips shown or affecting circumstances, were associated with more effective encoding in working memory. The individual differences explored considered other factors to explain the relationship (early-life stress and current mood states). Phasic adrenergic responses (fight-or-flight) had a role in working memory consolidation, but there are some moderators of this role. Overall, findings suggest that if the stress response is more negative, it helps people encode information faster into their working memory. Stress responses were not found to affect how much information was stored in participants' working memory. These findings suggest that the presence of arousal and negative affect is related to cognition.

Bradley and Lang (2007) consider emotional content when viewing images. Late positive potential is a response to emotionally engaging stimuli for around 400-700 ms after viewing a picture (e.g., Cacioppo, Crites, Gardner, & Berntson 1994; Cuthbert, Schupp, - Bradley, Birbaumer, & Lang, 2000; Huang & Luo, 2006; Keil et al., 2002; Palomba, Angrilli, & Mini, 1997). Viewing emotional pictures compared to neutral pictures resulted in a larger late positive potential for participants. The greatest effect was for simple figure-ground images with emotional content. The late component was found to be related to the emotional content of images rather than image properties (i.e. - color, contrast) themselves. Compared to previous studies, aversive pictures had more of an effect than positive pictures (e.g., Cuthbert et al., 2000; Palomba et al., 1997). Still, positive images had more of an effect on late potential than neutral pictures.

Lu (2015) looks at how color and contrast influence fearfulness ratings on natural scene pics (with different content and fearfulness levels). Previous studies had one type of picture, but Lu's study combined varying images one would see in daily life. Lu found that overall discrimination of fearfulness was greater for the high contrast stimulus. That is, high-contrast images were more fearful, and less-contrast images were less fearful. Overall, images can evoke different levels of fearfulness naturally. Cognition is related to emotion (Bradley & Lang 2007, Lu 2015, etc.).

Nielsen & Mather (2015) looked at whether handgrip elicits sympathetic arousal. They looked at hand grip without baseline maximum voluntary contraction (MVC) measurements. Cycling women and women on contraception used a hand therapy ball, and did one of two hand grip exercises: they did 30 percent MVC level for three minutes or 3 cycles of maximum MVC level for 18 seconds (1 minute rest in between). The 18-second task group had more increases in pupil dilation. Maximum handgrip exertions were found to be related to sympathetic arousal. Sympathetic arousal refers to the sympathetic nervous system's response to dangerous situations, to either fight or flee. Overall, physical effort is related to the fight or flight response. These results were found even when not calibrating for MVC before.

Bradley & Lang (1994) found that different physiological and behavioral responses are related to different parts of affect (pleasure + arousal) (Greenwald, Cook, & Lang, 1988; Lang et al., 1993). As an example, as pleasure decreases, so does heart rate and skin conductance. An example related to the present study is that physical action can be related to pleasure and arousal, based on context. Given the variety of potential responses to affect, you can expect different effects and changes in emotional responses to physical action. Nielsen and Mather, and Bradley and Lang found that physical effort is related to arousal.

We have considered research that looks at how physical actions, such as handgrip, affect cognitive tasks and emotional responses. We also have seen research on how arousal is related to working memory, emotion processing, and attention. Overall, through a review of past literature, we have seen precursor steps and ideas on the relationship between physical effort, cognition, and arousal. Specifically, we have found how cognition influences emotion, that physical effort is related to cognition, as well as how physical effort can be related to arousal. While these relationships have been established in past literature, understanding how they interact is important for the present study.

Building upon this theoretical foundation, we will explore this potential relationship of physical effort and cognition together on arousal in the present study. We will be focusing on arousal, exploring that aspect specifically. Zhang(2022) looked at negative arousal on cognition, so we will be looking at arousal regardless of valence in this study. Zhang has seen the effects of arousal and negative affect on cognition. In addition, Lu (2015) has seen a relationship between fear (a negative emotion) and cognition. That is, high-contrast images are more fearful than low-contrast images. Perhaps, there may be a relationship between arousal in general on cognition, along with physical effort. That is the question we will tackle in the present study. By using methods and considering gaps from previous literature, we hope to expand on our understanding of the relationship between cognition on arousal, with the moderator of physical exertion. If physical action and cognition are related, and arousal and cognition are related, there may be a relation between all three. Motor actions are a common moderator of the relationship between arousal and cognition in real life, which we attempt to explore. Exploring this potential relationship could apply to the real world because the real world is complex with multiple levels of interactions. This is a topic in which more research can benefit our daily lives, emphasizing the importance of working to understand how cognition is related to arousal.

Bradley and Lang (1994) explained that physical action can be related to pleasure and arousal, based on context. We will consider whether the exertion force of handgrip when watching images affects one's perceived rating of arousal. Hand grip is a measure of physical action and we will see its effects on arousal when viewing images of different levels of arousal simultaneously. It is predicted that arousal ratings with the concurrent hand grip task will increase with exerted handgrip force.

METHODOLOGY

STUDY PREVIEW

There is a total of one session for the study, lasting a total of one hour. Participants will begin the session with Maximum Voluntary Contraction (MVC) calibration at the start along with 5 practice trials. First, participants will see a series of photos with varying arousal all at once. Then, the trials with handgrip and arousal ratings begin. They will be prompted in each trial to exert either 5 percent or 45 percent of their maximum grip strength and view images with different levels of arousal. Then, they will see the photos again and select an arousal rating on the Self-Assessment Manikin (SAM) 9-point scale. They are requested to keep their grip steady.

PARTICIPANTS

Participants consist of undergraduate college students at the University of California, Riverside (UCR). Data collection is in progress as of now. The study takes place on the University of California, Riverside campus. Participants are required to be at least 18 years old, have a normal or corrected-to-normal vision, and have normal color vision to pass pre-screen requirements. They will provide written informed consent prior to the experiment, based on a protocol approved by the Institutional Review Board of the University of California, Riverside(Zhang 2022). Participants may sign-up up until 12 hours before the study appointment time for the study named "Visual Attention". Sessions last one hour and there is a total of one session for the study. They will be granted one credit on UCR's SONA system, which is the campus's Department of Psychology research participation system. Often, students in introductory psychology courses are required to gain SONA credits by participating in research studies as a participant, as part of an interactive component in their courses.

APPARATUS AND MEASURES

Maximum Voluntary Contraction (MVC)

This is the baseline measurement, also described as maximum muscular strength. The value is shown with a percentage, and the value varies between individuals.

Physical Exertion

Physical Exertion is measured through a hand dynamometer, that looks at isometric muscle contraction (Park 2021). Participants will squeeze the hand dynamometer with either low or high physical exertion (5 percent or 45 percent). 5 percent is the low physical load condition and 45 percent is the higher physical load condition. Physical action is associated with arousal, especially at a medium level (Park et al. 2021; Davranche et al., 2006; Droit-Volet & Berthon, 2017; Yerkes & Dodson, 1908). Given this idea, also described as the Yerkes-Dodson Law, the higher condition for physical exertion was 45 percent muscle contraction.

Arousal Scale

The Self-Assessment Manikin (SAM) scale is used in the experiment to measure arousal. The SAM 9-point scale measures pleasure, arousal, and dominance in response to different stimuli (Bradley & Lang). In the scale, from left to right means the least arousal induced to the most arousal induced. In other words, from left to right, your feeling of being alerted or excited is from weakest to strongest. It is a graphic scale and quick to fill. This works well with the present study because participants will view many images. There is a human figure to choose, which makes it clear that the focus is on one's sense of control over the image reaction. The SAM scale is a conventional scale that works with a variety of populations, from college students to older adults.

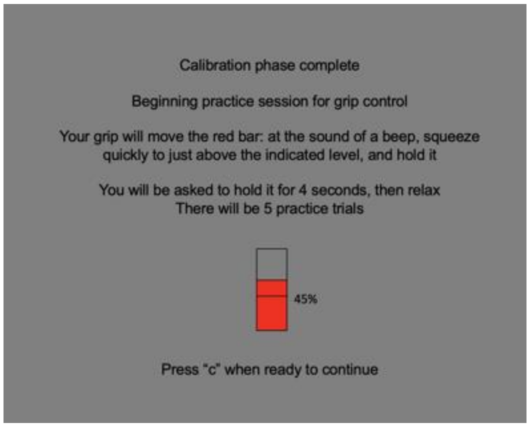
Visual Stimuli

Images of various arousal were selected from the International Affective Picture System (IAPS). The IAPS has common images in psychological research that generate emotional responses (Bradley & Lang). It has reports from pictures varying in valence and intensity. The pictures are associated with pleasure and arousal. For increases in pleasure or displeasure from viewing images, there are also increases in ratings of arousal. Something to note is that it has been shown that age and mental illness affect one's arousal levels. Images may have different effects on arousal for those who engage in abnormal behavior. In the present study, images from the IAPS are of various arousal. There is no valence attached to the images chosen.

PROCEDURE

Before participant arrival, experimenters should ensure the Vernier handgrip is well connected to the computer. Participant information and consent forms should be prepared. Headphones should be prepared if two participants will be performing experiments simultaneously.

When participants arrive, they will be asked to sanitize their hands. They will be able to wear gloves if they wish. They will then complete the study consent form and complete online participant information. After, maximum handgrip strength is measured with the hand dynamometer. Participants are informed to use the small muscles in their left hand to exert strength and avoid using big muscles in their arms, chest, or back to exert strength. They should keep the black cord upward. They should continue to hold the handgrip the same way throughout the entire experiment. After the beep sound, they are asked to hold the handgrip as hard as they can for 4 seconds, and 3 times. During this process, they should keep their left hand on the table or leg all the time. Participants are encouraged to maintain their grip level during the trial. After 3 times, the MVC number appears on the screen.



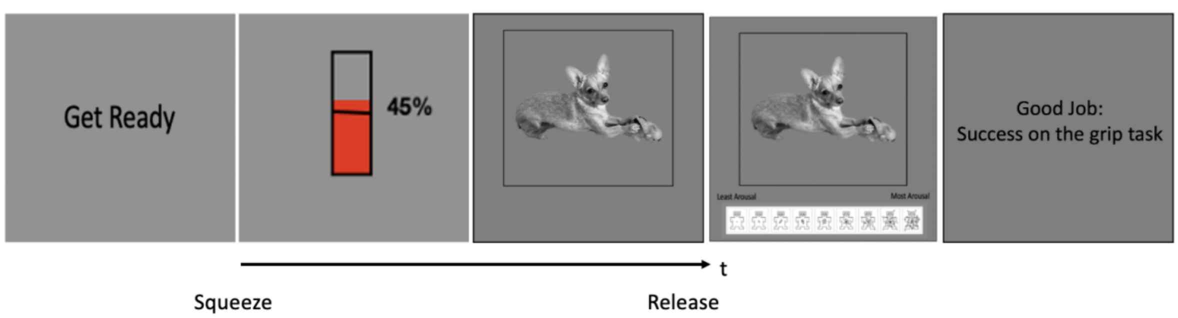
(Figure 1)

Next, participants will see a percentage indicating that they need to squeeze the handgrip to the percentage of their maximum strength for 4 seconds(Figure 1). The height of the red bar will give them immediate feedback about how strong they are squeezing at the moment. They are informed to squeeze above the indicated level of the black line, but also to not overshoot. For example, they may need to hold the handgrip to a little bit higher than 45% of their maximum strength for 4 seconds for the 45% exertion trial. After calibration, there will be 5 practice trials. After practice trials, the main experiment will begin.

For the first part of the task, participants will see a series of black-and-white photos of different arousal displayed on their screen. They will watch all the photos and further instructions will be given after viewing all the photos. In the second part of the task, they will see the photos again while holding the handgrip and will be asked to rate the arousal level they think each photo is. (Figure 2)

At the start of each trial, participants will see a "Get Ready" Prompt. They will engage in a handgrip and viewing dual-task procedure. Then, they are told to hold 5 percent or 45 percent grip force, which shows individualized MVC and is random for the trials. The 5 and 45 percent levels are meant to depict low and medium physical effort in the trials. This handgrip allowed them to look at physical effort, separate from muscular strength and natural individual fitness level. They can see their level in real time through a red bar with a line marking the grip level to reach. They are told to grip until they slightly pass above the black indicated line but to make sure they do not go too high, and to continue to hold the hand grip at that set level until instructed to release.

When they reach the target, they hold at that level while watching a picture they have seen before in the first run. Then, they will see an arousal scale (Self-Assessment Manikin(SAM) 9-point scale). They are informed to release their grip at the time they see the arousal scale to select the level of arousal induced by the picture they just saw for each trial. Participants are asked to avoid clicking the same response and to vary their response levels of arousal throughout the duration of the task, to account for potential biases. They will receive feedback on their grip accuracy (i.e. - “Success on the grip task”).



At the start of each trial, you'll see a "Get Ready" prompt followed by a bar representing either 5% or 45% of your maximum grip strength. Your objective is to grip slightly above this target level without overshooting. A red bar will show real-time feedback of your grip strength. Once you reach the target, maintain that force as you watch a picture you viewed before. When an arousal scale appears, release the grip and use the mouse to select how much arousal the picture induces. Please avoid clicking the same response rating throughout the entire task and make sure to spread out your responses as much as possible. You'll then receive feedback on your grip accuracy. Remember to keep your grip steady.

(Figure 2)

When participants work on the experiments, their grip accuracy is monitored. If Grip Accuracy becomes lower than 50%, they are informed to pay more attention to maintain steady strength during their break. The correct response rate of arousal is recorded, in which the response is deemed correct if participants choose an accurate level of arousal (low or high). If the correct response is less than 70%, then researchers will confirm how participants understand the arousal scale. It should be how strong one's feeling is, rather than how positive or negative. Researchers should take notes about unusual situations (e.g. Participants cannot learn the requirement) and give credits to eligible participants completing their visit.

Between blocks, participants have access to a tennis ball, ping pong ball, or a cup to help relax their hand muscles. They also have snacks prepared for them. These items will be beneficial because fatigue and tiredness may occur from the experiment's behavioral task. After each day of the experiment, there is an online participant information form for research assistants to complete. Additionally, participants in SONA should be granted credit.

POTENTIAL LIMITATIONS

In the experiment, a potential limitation is that participants may put a lot of focus on handgrip task success. Previously, Park(2021) considered the limitation as well, that participants may have chosen to focus on the distractor, expending cognitive effort for doing so. A potential change they suggested is to hold the grip for a certain amount of time to account for biases(2021). They explain the limitation may be attributed to the controlled laboratory setting of the experiment, which may not fully represent the real-world environment. To help mitigate this bias in the present study, we instruct participants to release the hand dynamometer before choosing an arousal rating. This helps minimize disturbance from hand grip exertion power on the participant's arousal ratings. Careful design helps get closer to accounting for the real-world environment, but more research is needed to generalize findings.

Another limitation could be that the sample size is college students, so this may limit applicability to other populations, such as older adults. However, the SAM scale is known for being applicable to a variety of populations(Bradley & Lang). Future studies may consider physical effort and arousal in different populations, maybe K-12 populations or older adults. In addition, self-report bias is a big limitation, similar to other studies with self-report ratings and scales. Participants are encouraged to vary arousal responses and this is stated clearly in the protocol as well as when study instructions are explained verbally. Participants are told to avoid clicking the same response and to be mindful about selecting different responses. We acknowledge that though we have helped minimize the chance of this bias, self-report bias is still a common and strong bias. The potential altering of results due to self-report bias should be kept in mind and study sample size should be considered, especially to assess the generalizability of the present study results.

Perhaps, individual differences may account for arousal ratings, such as current or prior mental health issues or mental illnesses. Mental health issues or mental illnesses may result in different ratings of arousal. As an example, a person with ADHD may have lower arousal at a certain point in time which would affect their ratings. ADHD adolescents stay in a state of autonomic hypoarousal, since they have a lower skin conductance level (SCL) and reduced number of non-specific skin conductance responses (NS.SCRs) compared to normal control subjects (Lazarro et al. 1999). Recent research looks at the relationship between ADHD and arousal. Bhattacharyya (2022) looked at an integrated device, called MAHD (Measuring Attention and Hyperactive Disorder), to analyze ADHD subjects. Through EEG signal measurements of 3-5-year-old preschoolers, EEG waves from the subjects with hyperactivity were found to be related to relaxation. Potentially, ADHD subjects may choose lower ratings of arousal than others because of their natural state.

DISCUSSION

Given the common occurrence of the action-cognition relationship, as well as that cognition is related to arousal, understanding the relationship between physical action and cognition with arousal is a unique and crucial area to study. The present study aims to assess how physical effort (handgrip exertion) while viewing visual stimuli affects arousal.

The prediction is that an increase in exerted handgrip force will be associated with an increase in arousal ratings. The reasoning is that physical effort is predicted to be associated with arousal, based on previous literature. First, physical action is associated with cognition as well as arousal. In summary, the higher hand grip condition (45 percent grip force) can be described as a moderate handgrip force. Physical action is known to generate emotional arousal most at a moderate level (Park et al. 2021; Yerkes & Dodson, 1908, etc.). In addition, physical action is related to cognition, as a higher hand grip force is associated with being able to block out a distractor for better visual search task performance(Park et al. 2021). Also, cognition is associated with arousal. Zhang (2022) found that negative arousal is associated with cognition, as a higher stress response was associated with better memory encoding abilities. The final relationship to be considered is physical effort and arousal, which is the focus of the present study. Nielsen & Mather (2015) found that the condition with maximum muscular contraction had higher pupil dilation, so higher sympathetic arousal. They specifically look at sympathetic arousal, so this present study is expecting similar results. In general, we expect physical actions to be connected with the mental, including how excited/alert we are. Overall, we anticipate that physical effort (i.e. - handgrip exertion) will influence cognitive processes as well as arousal responses.

The present study variables and methods have been adjusted based on previous findings from literature to attempt to build on current findings. Previous research has focused on negative arousal in relation to cognition(Lu et al. 2015, Zhang et al. 2022, etc.) The present study focuses on arousal in general, with no specifier on positive or negative arousal, or even the suggestion of positive- or negative-oriented terms. What this allows is the focus on the body being in a heightened are more alert state in general, and not just in terms of feelings such as anxiety, stress, and fear. This allows for the development of understanding in a more broad sense of arousal and its relation to cognition and physical action. In addition, the present study considers the added component of physical exertion (low or high physical load) for cognitive processing and arousal. Previous research has considered physical exertion and its effect on arousal(Zhang et al. 2022, Park et al. 2021, Nielsen & Mather 2015, Bradley & Lang 2007, etc.) but not so much about physical exertion, cognition, and arousal. The present study involved a handgrip instrument, varying images, and an arousal scale. This design also has adjustments from previous studies. Lu (2015) explained how previous research would have one type of picture in terms of style for the trials, but he and his team switched to varying images in contrast and color as one would see in everyday life. Lu used the International Affective Picture System (IAPS) as the source of these various images, and so does the present study. Following Park (2021), we will be using a low and medium physical load, based on their differences in the level of arousal. For the task itself, we will ask participants to release their handgrip before choosing an arousal rating so they aren't influenced by the focus needed to maintain the handgrip with the hand dynamometer.

If we find through data analysis and other literature that the prediction is supported, cognitive and physiological aspects would be important to understanding emotional responses such as fear. These findings can apply to daily settings as well as clinical interventions. As an example of a clinical intervention, you can learn about the potential emotional reactions of patients, to overall improve their mental health and well-being during treatment (Bradley & Lang 1994). In a K-12 setting, fidgeting may be controlled through physical activity or physical exertion such as a stress ball. The physical activity may directly result in changes in arousal, as differences in fidgeting behaviors due to arousal were found to negatively affect neural activity (Patrick 2019). In daily life, weight-lifting is an activity that makes you feel pumped up. Perhaps, lifting weights between sets of work can help with feelings of arousal or excitement when doing work tasks. Muscular strength would play a role in weight-lifting as opposed to handgrip, but as this is real life it wouldn't have as much of an effect as it would in the present study. Still, more research relevant to the physical activity, cognition, and arousal relationship can help increase the viability of this idea.

We hope future research continues to consider the relationship between physical action and cognition on arousal. Perhaps, research can consider physical activity, such as weight training as discussed above, instead of physical effort as a measure of arousal ratings. As opposed to physical effort, research on physical activity can be carried out in the lab and into the real-world environment. This would help establish the relationship between physical action and arousal in literature. In addition, it would be more convenient in terms of less equipment needed. However, there may be disturbances or difficulties in collecting data in a naturalistic environment.

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