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How visualization influences strength endurance

Joshua Moore[1], Danielle Graham[2]
[1] Oakleaf High School, Orange Park, Florida
[2] Unaffiliated author

SUMMARY

This study examines how differing degrees of visualization, the process of mentally conceiving a visual image, could influence strength endurance, which is defined as the strength output over longer durations of muscle tension. It's worth note, this research isn't generalizable considering researcher and sole participant are the same in this case study. Instead, the research aims to assess a potential relationship that could call for further exploration in future studies. Thus, this study is exploratory in nature, as it merely investigates a question previously unstudied in depth. We hypothesized that improved visualization of the lifted weight would increase strength endurance. To evaluate this, we performed a sample set of minimally weighted repetitions until failure before completing each set of weighted repetitions, under each condition, until failure. The blind-weight unknown condition would keep visualization inaccurate. The blind-weight known condition would allow for more accurate visualization. The sighted condition would allow for a precise visual. Contrary to our hypothesis, our results suggested that people, when lifting heavy objects, were able to hold out against mental fatigue longer when they were unable to accurately visualize what they lifted compared to when they were able to accurately visualize what they lifted. These preliminary findings serve as a call for future scientific investigations into this very subject.

INTRODUCTION

Research has conveyed how the power of perception, specifically in illusions like the Size Weight Illusion (SWI) where identically weighted small objects will feel heavier than their larger counterparts, is unlikely to affect strength endurance when lifting weights (1); SWI was found to neither significantly influence exercise output nor post-workout fatigue (1). However, the presence, or lack of, vision, has affected the way we act on the SWI, showing an interference in motor recalibration for grip/load errors (2). The current evidence does suggest expectations drive the amount of force we use to lift when in absence of vision or knowledge of weight load (2, 3).

On the more cognitive side of these psychophysiological connections, it is known that in endurance exercise, the mind plays an important part in deciding when to quit by limiting or reducing motivation and by increasing perception of effort (4, 5). Though not affecting maximal strength, mental fatigue also has influence within the central motor command (4); mental fatigue is the slowing of cognitive faculties resulting from extensive "demanding cognitive activity" (4). The research which has proven that appraisal of task demand can affect exercise endurance further emphasizes endurance's connection with the process of cognition (5). In addition to mental perceptions of difficulty, attention is an important part of the psychophysiological relationship. The constrained action hypothesis claims that a conscious effort to control one's own movement overrides motor processes meant to handle movement instinctively, and explains why directing focus toward one's movement as opposed to an "implement," or weighted object, reduces motor efficiency (6). While attention and mental imagery, which this study examines, are distinct mental functions, attention itself is still typically plays an important role in imagery, so their influence on strength endurance may overlap (7).

Focusing more on imagery, pre-visualization of a movement can improve strength when executing said movement (8). Researchers have attributed these effects to there being higher odds of a positive internal state when visualizing, as well as the potential priming of motor neurons for efficiency. A positive internal state refers to one's internal sense of composure resulting from their internal condition – in relation to motivation (8). There is also evidence of a neurobiological link between perception and strength output; one study has shown that when lifting unknown loads, uncertainty could work as a potential stressor (3).

The psychophysiological element present in weightlifting has intrigued psychologists for decades. While there has been much research on links between endurance and perception, there has been little in the way of how one's visualization of a weighted object affects their strength endurance. This exploratory study aims to investigate whether differences in visualization influence a person's ability to sustain strength. The inability to ensure proper visualization and participants' lifting capabilities limits some of the studies done in this area; limits arising in everything from troubles guaranteeing proper, and suitable amounts of, visualization across participant groups over 130 strong, as well as including groups with "no experience in manual lifting tasks" (6, 8). As such, this study accounts for these limitations due to its unorthodox nature; the researcher is also the weight-trained subject, which assures proper visualization and capability. The influence of actual sight must also be explored here, considering the established influence of actual sight on muscle power (9).

These studies help provide a better contextual understanding of how perceptual, cognitive, and imagery-related factors of the psychophysiological relationship influence strength endurance. A reasonable assumption, based on the current research, was that with lack of sight already reducing muscle output, strength endurance would further diminish on account of mental fatigue spurred by the cognitive stress of uncertainty (3, 4, 9). Accordingly, we hypothesized that as visualization of the weight lifted improved, strength endurance would increase. In the end, while there was no statistically significant difference between our conditions (p = 0.088), heart rate was lowest during the blind, weight unknown condition and there didn't appear to be any sizable difference between push and pull exercises; future researchers should consider visualization's effect on movement type as opposed to movement itself.

RESULTS

Initially, in the "blind, unknown" condition, the participant would lift the heavily weighted set blind and without knowledge of the mass. Next, in the "blind, known" condition, the participant would lift the heavily weighted set blind, but now with knowledge of the mass. Finally, in the "sighted, known" condition, the participant would lift the heavily weighted set fully sighted and knowledgeable of the mass. Each condition contained both a push and pull set, preceded by an unconditioned, minimally weighted, benchmark set **(Table 1)**.

	Baseline reps	Weighted reps	Baseline reps (trial no. 2)	Weighted reps (trial no. 2)
Condition 1 (Pull)	46	25	36	14
Condition 1 (Push)	63	20	59	24
Condition 2 (Pull)	42	22	51	20
Condition 2 (Push)	73	21	90	27
Condition 3 (Pull)	43	24	40	22
Condition 3 (Push)	74	20	80	24

Table 1: The Raw Data. Both minimally weighted (baseline) and heavily weighted (weighted) reps, organized by condition, and weight. Recorded via tally counter during both sets of each condition; condition 1, "blind, unknown;" condition 2, "blind, known;" condition 3, "sighted, known." Pull denotes the pull exercise. Push denotes the push exercise.

Taking each difference between weighted reps and unweighted reps, from every condition **(Figure 2)**, their corresponding Z-scores were calculated **(Table 2)**. Notably, Z-scores for condition 1, "blind, unknown," never flew higher than about 0.0127 **(Table 2)**. A far cry from the highest Z-scores of conditions 2 and 3, roughly 0.7594 and 0.3441 respectively

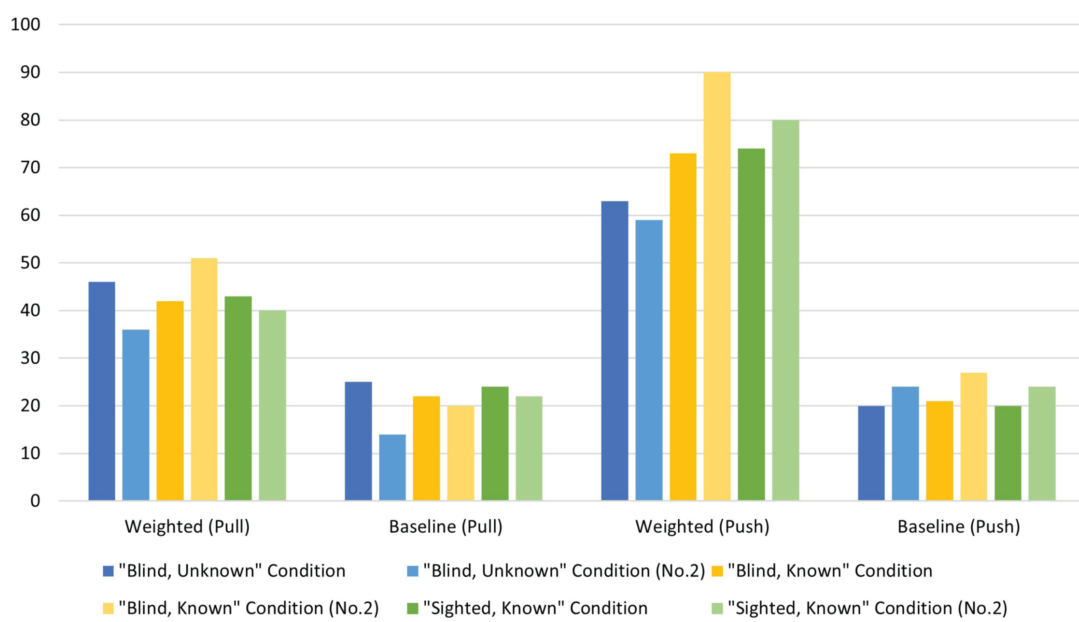

Figure 1: Number of reps by weight. The respective number of reps recorded in both trials, categorized by weight; whether a given set was weighted or with baseline weight. Blue colors signify the blind, weight unknown condition (Condition 1). Orange colors signify the blind, weight known condition (Condition 2). Green signified the sighted, weight known condition (Condition 3).

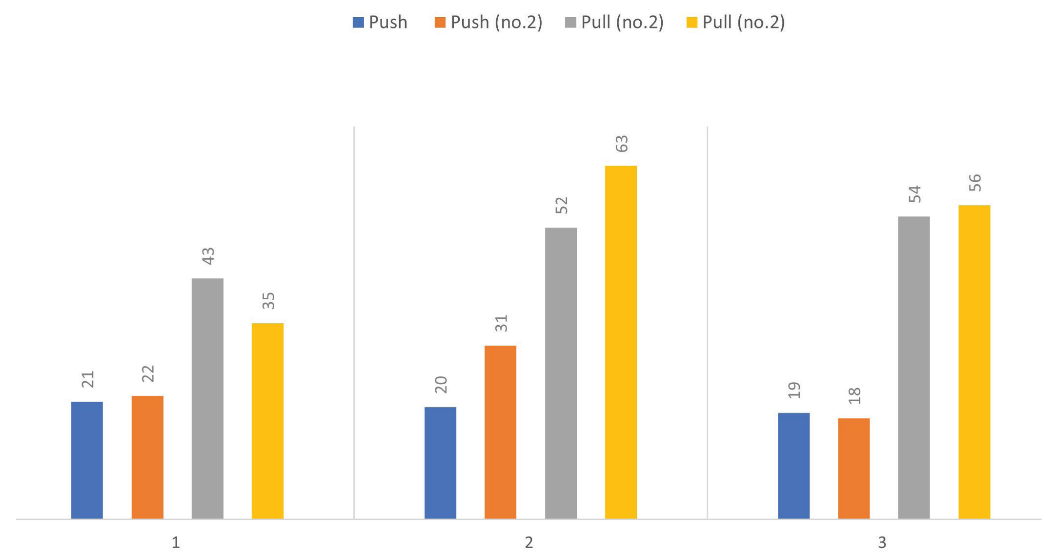

Figure 2: Difference in sets. The respective number of reps recorded in both trials, categorized by weighting; whether a given set was weighted or with baseline weight. Blue colors signify the blind, weight unknown condition (Condition 1). Orange colors signify the blind, weight known condition (Condition 2). Green signified the sighted, weight known condition (Condition 3).

(Table 2). Looking at the numbers, condition 1 also had the lowest average of reps, at 20.75, while both conditions 2 and 3 held an average of 22.5 respectively **(Figure 1)**.

With this **(Table 2)**, an ANOVA test analyzed all conditions. It found an F-value of 3.224 (p = 0.088); although failing to reject the null hypothesis, it's perhaps notable that if performed without inclusion of data from Trial 2, the ANOVA produces a lower F-value of 0.047 (p = 0.954); potentially implying low sample size could be a main factor in hindering results. Lastly, an ANOVA of average heart rate per condition found an F-score of 5.191 (p = 0.106) which was not statistically significant either **(Table 3)**; however, the fairly small sample size for this data may be a factor, it should also be noted that heart rate (bpm) was lowest during the blind, unknown condition **(Table 3)**.

	Z-Score (Pull)	Z-Score (Push)	Z-Score (Push no.2)	Z-Score (Push no.2)
Condition 1	-0.05093	-0.42717	0.012733	-0.9018
Condition 2	-0.1146	0.106792	0.585725	0.759407
Condition 3	-0.17826	0.225449	-0.24193	0.344106

Table 2: Z-score differences. Z-score of differences between "minimally weighted" and "weighted" reps by each of the three conditions. Calculated from the number of reps recorded by spotter. Measures how far each recorded number of reps strayed from their exercises' respective averages. The designation no.2 indicates which results came from the second trial.

DISCUSSION

In all, while no statistically significant evidence was found that fully confirmed nor denied our hypothesis, Condition 1 "blind, unknown" tended to have a lower difference between weighted and baseline sets compared with conditions 2 and 3, "blind, known" and "sighted, known" respectively. This would hint toward findings that suggest visualization can improve lifting efficiency (8). However, visualization occurring in this study only began just before, and during, commencement of the lift. Thus, the proposed theory of visualization's impact on positive internal state seems more plausible than the theory of visualization's priming motor neuron pathways; while studies on neural priming haven't determined a definitive duration required, they've generally stuck around a whole "15-20 mins" (10). With consideration of this study's exploratory limitations, it is possible that with less knowledge to base one's visualization on, the less one's biased preconceptions may hold sway. This could explain why strength endurance persisted longer on average in the blind, weight-unknown

	H.R. (Push)	H.R. (Pull)
Condition 1	84	97
Condition 2	122	123
Condition 3	101	122

Table 3: Avg. heart rate. The average heart rate (H.R.) in beats per minute recorded during each exercise, of Trial 2, by condition. Heart rate was tracked by a wrist mounted fitness tracker and later retrieved from its database.

condition as opposed to the blind, weight-known condition; without supposed preconception related stressors, appraisal of task demand may be lower, which research has shown to improve performance (5). In the future, research on this subject should measure how participants assess difficulty of certain weights prior to lifting, as well as after.

There are some major limitations to this study, foremost that the researcher is also the sole participant. The nature of this research means that it is not necessarily generalizable to the greater populace. As previously stated, this study's intention was to merely uncover the possibility of a phenomenon that may afflict broader society. Additionally, this means statistical power is highly limited, so there is a chance any effects observed were the product of statistical error; future research would do well to incorporate far larger sample sizes. Other principal factors for consideration are the concepts of self-fulfilling prophecy and researcher bias. The former, which is when the beliefs and expectations of others or ourselves influence our actions to induce expected outcomes, does not seem to be a factor here as the results contradicted expectation (11). The latter, which is when researchers unintentionally implement systematic errors into the experiment or misinterpret results to conform with their expectations, also does not appear relevant as this study included numerous measures to strictly limit the researcher's influence during the experiment to only that which was necessary for recorded observation as a subject (12). Lastly, while spotter error was a potentiality, the experiment's design ensured that any administration or data collection errors could be detected immediately, and none were.

Another potentially interesting takeaway is within the study's exercise composition. In prior research, few, if any, have examined visualization's effects across differing muscle groups. When standardized, both pull and push exercises followed a similar trend. While not concrete, as this is merely an exploratory study, this data could suggest visualization influences both motor retraction, or pull movements, and motor extension, or push movements, equally. One explanation for this may be that visualization affects movement in general, not merely the type of movement. This lends credence to the positive internal state theory on visualization as a positive internal state shouldn't differ across bodily movements either. Future researchers should consider this distinction in their studies.

MATERIALS AND METHODS

The sole participant is an experienced lifter with 2.5 years of weight training. During the three experiments, the subject's weight averaged at approximately 137.7 pounds. At 5'7", the participant is 16.6 years of age (17.1 as of replication), male, and of African American ethnicity.

To conduct this experiment, a sleep mask served as the blindfold, which was critical for the first two conditions. The spotter maintained a keychain around their finger with tally counters attached to help them count in real time. The spotter recorded data, consisting of the number of reps alongside the weight being lifted, on 20 cm x 13 cm observation forms sealed in labeled manila envelopes that indicated both exercise and condition; heart rate, measured during the replication study, was recorded on a fitness tracker, then extracted following the experiment's conclusion.

Two exercises were performed in this experiment, a push exercise and a pull exercise. The push exercise was a standard bench press, requiring a flat bench and a standard barbell; in this exercise, one uncracks the bar from a horizontal position, lowering to their chest and pressing it back up. The pull exercise require a standard cable row machine; in this exercise, one pulls back two pulleys from an upright, siting position, with their back straight.

In this experiment, each condition started with the pull exercise on the seated cable row machine, followed by the push exercise via bench press. These exercises, per condition, would consist of one minimally weighted, preliminary set with 45 lbs. of weight, then the conditioned and more heavily weighted set. The spotter received a range of weights to choose from between 55-125 lbs. for the cable row, and 65-135 lbs. for the barbell. These ranges roughly corresponded to between 33% and 66% of my one rep maximums, 205 lbs. and 190 lbs. respectively. All of this helped reduce any reliable visualization in the first condition while also ensuring the weight would not cause injury. The spotter recorded each set, until failure to complete another rep, with tally counters, and placed them in the envelope labeled with their respective exercise and condition. After every exercise, the spotter subsequently filled out the aforementioned observation form, containing reps counted and weight lifted, which also went into the envelopes; the spotter sealed the envelope concluding each exercise. The study's three different conditions always occurred on three separate days, with a spotter's assistance. Each lifting day was two days apart from the last lifting day, except for one which was three days apart; barring mundane functioning, no strenuous physical activity or exercise occurred in these intermission periods.

In the first condition, the participant lifted heavily weighted sets with a sleep mask on and kept it on until the spotter removed all the weight. While the spotter and participant were in the same room when the rubber weights were loaded on, the participants hands remained covering their ears until being tapped on the shoulder by the spotter. Still, sound was merely muffled, not silenced. The second condition ran exactly as the first but with the spotter announcing how much weight they had loaded on just before the lift. For the third, and last, condition, the participant did not wear the sleep mask, but the spotter did still announce the amount of weight loaded on. When replicating this study, conditions changed order and heart rate was recorded foreach condition via a fitness tracker around the participant's wrist. The heart rate data was stored in the tracker and uploaded after all conditions were completed and recorded. The sighted condition was first. The blind, known weight condition was second. The blind, unknown weight condition was last. Keeping the blind, unknown condition fully unknown, the spotter had to calculate the weight difference between both weighted and minimally weighted in previous sets. Choosing a minimal weight between 45 and 75 lbs., the minimally weighted set would occur blindly as well, then the weighted set would include the calculated difference. This controlled for weight range.

All data was organized and analyzed in Microsoft's Excel by first compiling data observed onto a spreadsheet, then by utilizing its built-in data analysis functions as well. Each numerical difference between weights had their Z-score calculated cell by cell via Z-score formula; this standardized all differences by their standard deviations relative to their respective averages. For ANOVA, Z-score data was selected and ran through Excel's data analysis tool. Each group was comprised of the numerical, standardized difference between weighted and minimally weighted sets for each of the three conditions. The inference performed was a single factor ANOVA. The resulting p-value and F-value were recorded from the output table.

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REFERENCES

1. Buckingham, G., *et al.* "Weightlifting Exercise and the Size–Weight Illusion." *Attention, Perception, & Psychophysics,* vol. 76, no. 2, 2013, pp. 452–459., https://doi.org/10.3758/s13414-013-0597-8.
2. Buckingham, Gavin, and Melvyn A. Goodale. "Lifting without Seeing: The Role of Vision in Perceiving and Acting upon the Size Weight Illusion." *PLOS ONE,* vol. 5, no. 3, 2010, https://doi.org/10.1371/journal.pone.0009709.
3. Khalaf, Tamer M., *et al.* "Psychophysiological Responses to Manual Lifting of Unknown Loads." *PLOS ONE,* vol. 16, no. 2, 2021, https://doi.org/10.1371/journal.pone.0247442.
4. Schiphof-Godart, Lieke, *et al.* "Drive in Sports: How Mental Fatigue Affects Endurance Performance." *Frontiers in Psychology,* vol. 9, 2018, https://doi.org/10.3389/fpsyg.2018.01383.
5. Blanchfield, Anthony, *et al.* "Non-Conscious Visual Cues Related to Affect and Action Alter Perception of Effort and Endurance Performance." *Frontiers in Human Neuroscience,* vol. 8, 2014, https://doi.org/10.3389/fnhum.2014.00967.
6. Wulf, Gabriele, *et al.* "The Automaticity of Complex Motor Skill Learning as a Function of Attentional Focus." *The Quarterly Journal of Experimental Psychology Section A,* vol. 54, no. 4, 2001, pp. 1143–1154., https://doi.org/10.1080/713756012.
7. Thompson, William L., *et al.* "Dissociation between Visual Attention and Visual Mental Imagery." *Journal of Cognitive Psychology,* vol. 23, no. 2, 2011, pp. 256–263., https://doi.org/10.1080/20445911.2011.477810.
8. Hynes, Janette, and Zach Turner. "Positive Visualization and Its Effects on Strength Training." *Impulse: The Premier Undergraduate Neuroscience Journal,* 2020.
9. Killebrew, Shanna S., *et al.* "The Effect of Loss of Visual Input on Muscle Power in Resistance Trained and Untrained Young Men and Women." *Journal of Strength and Conditioning Research,* vol. 27, no. 2, 2013, pp. 495–500., https://doi.org/10.1519/jsc.0b013e3182577091.
10. Stoykov, Mary Ellen, *et al.* "Movement-Based Priming: Clinical Applications and Neural Mechanisms." *Journal of Motor Behavior,* vol. 49, no. 1, 2017, pp. 88–97., https://doi.org/10.1080/00222895.2016.1250716.
11. "APA Dictionary of Psychology." *American Psychological Association,* American Psychological Association, https://dictionary.apa.org/self-fulfilling-prophecy.
12. "APA Dictionary of Psychology." *American Psychological Association,* American Psychological Association, https://dictionary.apa.org/researcher-bias.