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Learning with Intrinsic Motivation Enhancement (LIME)

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Author Note: The authors listed above are currently seniors at the United States Military Academy at West Point and worked under the direction of their advisor, LTC Randal Hickman. They are working with Lockheed Martin's Advanced Technology Laboratory (ATL). The authors would like to thank Lockheed Martin and their advisor for all their support.

Abstract: Lockheed Martin is studying an automated system designed to optimize learning in remote environments without student-teacher interaction. The system will provide the optimal educational experience at the right time, motivating learning based on individual learning type and consistent levels of knowledge retention. Critical to this process is understanding the most effective types of motivation for learners. This research team developed an experiment at West Point's Engagement Skill Trainer (EST) simulation facility to compare the impact of various types of intrinsic and extrinsic motivation on cadet performance in marksmanship. Cadets motivated through intrinsic means outperformed both the cadets motivated through external sources and cadets in the control group. Biometric data also demonstrated that intrinsic motivation was correlated to lower heart rates during marksmanship training. This study shows that intrinsic motivation works on shooting ability and can act as a proxy for various learning environments. Educators or future research can investigate the implications of using intrinsic motivation in their classrooms or in other pedagogical settings.

Keywords: Intrinsic Motivation, Extrinsic Motivation, ANOVA, Biometric Data, Data Analysis

1. Introduction

Learning frequently occurs in remote locations, often without student-teacher interaction. Pandemic conditions highlighted this difficult reality in 2020, but Lockheed Martin has been developing an automated system to improve remote education for deployed servicemembers for the past three years. In the second year of its partnership with West Point on this topic, this research focuses on the motivation aspect of the computer-based education. Forms of intrinsic and extrinsic motivation are used to alter the learning environment, while experimental outcomes and corresponding biometric data show the impact of different types of motivation.

2. Problem Definition

Lockheed Martin has partnered with the Department of Systems Engineering at West Point to further study motivation categories and the effects of different types of motivation. The intent of the research partnership is to design an experiment that measures the effectiveness of intrinsic and extrinsic sources of motivation on experimental outcomes and corresponding biometric data. The goal of this research is to explore human reactions to different types of motivation while maximizing the effectiveness of the learning experience through appropriate motivation. Understanding human response to motivation types will facilitate the continued development of an automated learning tool for use by deployed servicemembers in a remote environment. The study uses the EST Range at West Point to test various forms of motivation to act as a proxy for any type of learning environment.

3. Engineering Design

3.1 Methodology

This study uses data to generate a greater understanding of how motivation alters performance and relates to learning. The research team designed an experiment at the Engagement Skills Trainer (EST) at West Point to measure the effectiveness of intrinsic and extrinsic motivation during marksmanship training events. Cadet performance and heart rates at the EST show the effectiveness of motivation types, and statistical analysis measures the effects of the injected motivation. Three types of motivation are analyzed. The first is intrinsic motivation, which is achieved through a series of survey questions that we intend to stimulate a deeper level of reflection in the participant, intrinsically motivating them (Kulkarni et. Al., 1970). The second is competition, in which an incentive was announced for the winner of the iteration. This is extrinsic motivation, and we intend this to motivate the participants to perform better than their group. Finally, the third is a combination of intrinsic and extrinsic motivation, connecting to the cadet's confidence. By providing an individualized explanation of where they stand and words of affirmation and encouragement, the intention was to increase the confidence of the participants and therefore motivate them to perform better.

In this study, changing marksmanship performance over time is a proxy for learning, with the assumption that increased performance means increased understanding of marksmanship and illustrates learning. By analyzing cadet performance at the EST range before, during, and after injected motivation, the impact that each motivation strategy has on one's performance are evaluated. Throughout the experiment, cadet participants' heart rates are also monitored. A lower heart rate during shooting indicates higher confidence in personal ability and lower reaction to undesirable stressors.

3.2 Execution

Volunteer participants were recruited from the Corps of Cadets at the United States Military Academy and distributed amongst seven experimental groups. The testing population consisted of cadets from all four classes during the spring semester of 2021. The same shooting tasks were conducted by each group under the same experimental conditions except for the changing motivation strategy as the independent variable. Two groups were assigned to each motivation strategy and one was left as the control group. Our metrics for performance were shooting scores out of 40 and group size, while our metric for stress and confidence were survey answers and heart rate.

Before shooting, all participants were required to answer a pre-survey to gauge the initial perceived confidence, ability, and experience levels of each participant. This evaluation provided a baseline prior to participants having their motivation influenced in the study.

The first shooting task for all groups was to calibrate their rifles to their shooting style by conducting a group and zero table. The group size essentially evaluates the consistency of one's aim as he fires his rifle. Once this consistency requirement is met, the rifle is then automatically zeroed by the system to ensure that the shooter is aiming at the target. The participants' heart rates were recorded before and after this event. Cadets then transitioned into the three-iteration simulated qualification. The first was a baseline shoot of twenty targets, in which participants were limited to twenty shots. After every iteration, there was a follow-up survey and heart rate check. To measure the heart rate, the heart rate monitor function of smartwatches was used. Between the first and second iteration and the second and final iteration, the motivation strategy was also applied based on the four groups (no motivation, intrinsic, extrinsic, and combination). At the conclusion of the last iteration of shooting, all test groups took a post-assessment survey. These questions are like the questions on the prescreening survey, allowing the research team to observe any differences between participant perception before and after the experiment.

The control group did not receive any motivational influence. They were only administered the surveys. This served as a control so that the research group could observe participant performance over time with no experimental factors. The "Intrinsic Motivation" groups were instructed to answer survey questions requiring them to reflect on each iteration of shooting (Singh et. al., 2004). The reflective questions administered to the participants of these groups allowed the participants to rate themselves on perceived ability, confidence, and potential implications on future careers (Puntambekar, 1999). The "Extrinsic Motivation" groups were influenced by the extrinsic motivation strategy, which was a competition between the participants. We also attempted to create an intense environment in which they were pitted against each other by purposefully identifying those excelling at the task and those doing poorly (Yueh et. al., 2015).

The "Combination" groups were subjected to a combination of these motivation strategies. The groups were encouraged to do their best and were fed positive affirmations by the research team. There was also an upbeat and encouraging speech given in efforts to illicit a heightened sense of motivation. They were not given notice that they would receive this communication beforehand. This is done intentionally to accurately measure the effects of this portion of injected extrinsic motivation.

4. Analysis and Findings

4.1 Performance

To assess the relationship between performance and motivation type, the final iteration of the marksmanship exercise participants completed was the focus. One cannot expect to see results of a treatment of this sort immediately, rather it takes time for participants to experience and internalize the type of motivation. By looking at the final iteration, results of multiple injections of and prolonged exposure to a motivation type are captured.

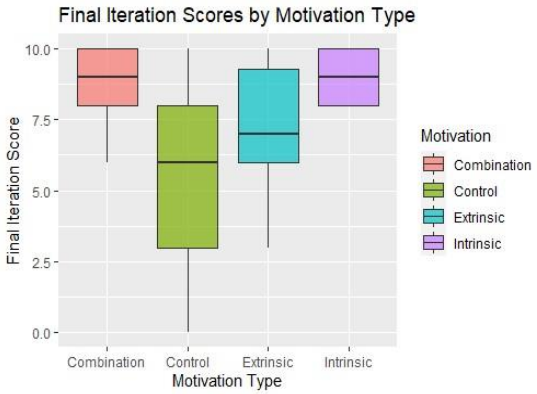

Figure 1. Motivation Type and Final Iteration Score Plot

Figure 1 is a plot of the performance scores and motivation types illustrates the difference between intrinsic and extrinsic motivation. There is a significant difference in shooting performance of groups under the intrinsic motivation treatment and the extrinsic and control group. It is important to note the similarity in intrinsic and the combination of motivation, most likely due to the presence of intrinsic motivation in the combination treatment (Thomas & Jansen, 1996).

Table 1. ANOVA Results for Motivation Type and Performance

	Df	Sum sq	Mean Sq	F value	Pr(>F)
Motivation Type	3	55.870	18.622	4.069	0.015
Residuals	32	146.440	4.576		

Table 2. Tukey Test Results for Motivation Type and Final Performance Iteration

	Diff	lwr	upr	p adj.
Combination - Control	3.300	0.125	6.475	0.039
Extrinsic - Control	1.850	-1.235	4.935	0.380
Intrinsic - Control	3.711	0.478	6.944	0.019
Extrinsic - Combination	-1.450	-3.932	1.032	0.402
Intrinsic - Combination	0.411	-2.252	3.074	0.975
Intrinsic - Extrinsic	1.861	-0.695	4.417	0.219

On average, the control group had a final score of 19.2 hits, extrinsic was next with 21.75, the combination group had an average of 25.7, and intrinsic had the most with 28.1. The relationship between motivation type and the score of the final qualification iteration is assessed using a one-way ANOVA followed by a Tukey test. The ANOVA, which looks at the potential

differences in testing groups, showed that motivation type is significant when comparing qualification scores (see Table 1). Upon a further analysis using the Tukey test, which conducts pairwise comparisons between groups, there is a statistical significance from the control for performance groups that were motivated intrinsically (see Table 2).

4.2 Heart Rate

The results of the heart rate analysis also follow the narrative that intrinsic motivation is the best motivation. Figure 2 illustrates again that the combination treatment is better than of the extrinsic, due to the inclusion of intrinsic motivation as well. On average, the control group had a heart rate of 83 bpm, the combination group 82, the extrinsic group 88, and the intrinsic group 76—the lowest of the treatments.

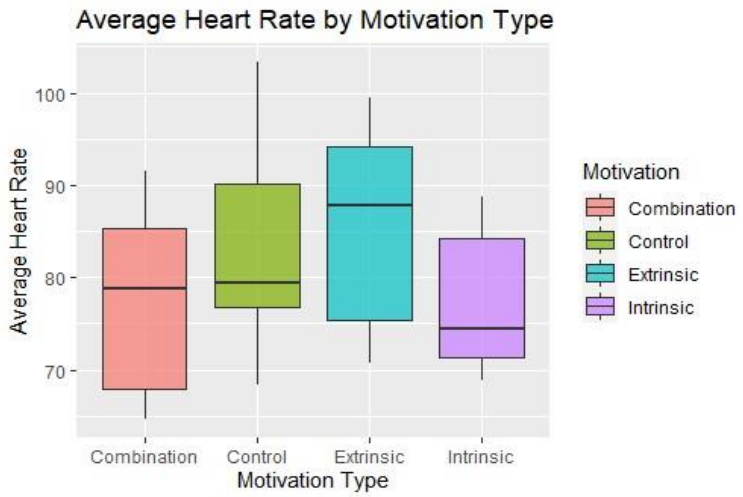

Figure 2. Motivation Type and Average Heart Rate Plot

In order to avoid lower heart rate being associated with additional weapon exposure and the natural comfort that comes from many qualification iterations, the first heart rate after receiving motivation was used to conduct the statistical analysis. A oneway ANOVA and Tukey test identify whether the same conclusion can be made with statistical significance. Tables 4 and 5 display the results for the ANOVA and the Tukey Test. There is a difference in heart rates, specifically in the intrinsic and extrinsic motivation types. The associated p-values are not low enough to prove this statistically, but they show some statistical strength in the ANOVA (0.315) and in the intrinsic-extrinsic comparison of the Tukey test (0.252).

Table 4. ANOVA Results for Motivation Type and Heart Rate

	Df	Sum sq	Mean Sq	F value	Pr(>F)
Motivation Type	3	588	195.900	1.230	0.315
Residuals	32	5096	159.300		

Table 5. Tukey Test Results for Motivation Type and Heart Rate

	Diff	lwr	upr	p adj.
Combination - Control	-0.600	-19.328	18.128	1.000
Extrinsic - Control	5.483	-12.717	23.683	0.846
Intrinsic - Control	-5.044	-24.116	14.027	0.890
Extrinsic - Combination	6.083	-8.557	20.723	0.677
Intrinsic - Combination	-4.444	-20.154	11.266	0.869
Intrinsic - Extrinsic	-10.528	-25.605	4.549	0.252

5. Discussion

The results of the experiment communicate the impact and significance of intrinsic motivation compared to non-intrinsic motivation strategies. Prior to conducting this experiment, authors hypothesized a higher number of targets hit correlates to a higher ability level and improvement, while a lower heart rate indicates a higher level of confidence and a smaller reaction to motivation type. To support this hypothesis, the optimal heart rate for an individual is defined as moderate to illustrate composure and motivation effectiveness. This original perspective served as a start point for the analysis, and we used heart rate to characterize the biometric impact of a given motivation type. Another primary performance measure used to identify the best motivation strategy was the number of targets hit because this metric was a common objective that all participants could work towards. The unique differences between intrinsic motivation and non-intrinsic motivation were analyzed using these performance measures. It is imperative to explore how intrinsic motivation led to statistically higher scores. In this study, intrinsic motivation differs from other types of motivation because an individual is challenged to conduct internal reflection using our formative survey. Questions on the formative survey included, "Is your previous score becoming of an officer?" As future officers, the participants have a vested interest in their shooting proficiency (Gagné & Deci, 2005). It is likely that the participants used their past experiences and desires to be a better officer to drive themselves to actualize achieving a higher number of targets hit (Baer, 2016). While intrinsic motivation is individualized, extrinsic motivation can only be generalized because it cannot influence everyone in the same way. For example, a few participants who were administered extrinsic motivation became excited, lively, and their ability to focus increased while the opposite occurred in other participants of the same group. This uniqueness in behavior can be attributed to differences in an individual's personality and social psychology (Braver et al., 2014). The results show that extrinsic motivation yields performance scores like that of the control group. Overall, this study suggests that intrinsic motivation leads to desired outcomes, and a possible explanation is that the individual caters their own stimulus in a manner conducive to themselves.

Heart rate metrics help to illustrate how the motivation type impacts an individual. Participants who were administered intrinsic motivation, and went through the respective cognitive process, had generally lower heart rates. This differs from an individual's response to extrinsic motivation because an individual must observe, interpret, then react to the given external stimulus. In this context, the primary distinction between intrinsic and extrinsic motivation is that an individual can mentally remove themselves from the influence of intrinsic motivation, while individuals cannot mentally remove themselves from the influence of extrinsic motivation. The extrinsic motivation cognitive process, especially when continuous, takes more mental and physical energy which can be attributed to higher heart rates. (Braver et al., 2014). According to the Tukey test, it cannot be concluded that the heart rate in subjects administered intrinsic motivation were significantly lower than heart rates in those administered extrinsic motivation. Assuming a significance level of 0.05, there are no combinations that indicate a significant difference in heart rate given a certain motivation type. However, the intrinsic - extrinsic p value, 0.252, is the lowest of the Tukey test comparisons. This suggests that intrinsic motivation heart rates and extrinsic motivation heart rates are more likely to have larger differences than other combinations in the Tukey test. Since a calmer heart rate is usually favorable, intrinsic motivation can be classified as the better motivation type biometrically.

Confounding variables must be accounted for in this analysis. First, some participants in the study were freshmen, and their limited experience may have skewed shooting performance. Additionally, most of the participants were male. Although this is a function of selecting participants from a male dominant pool, the limited diversity could have impacted the overall shooting performance results. However, this demographic was consistent in each of the seven experimental groups, mitigating any effect that may have biased one treatment over another. Additionally, in order to mitigate the effects of these confounding variables, the research group used randomization of assignment to experimental group and replication of treatments. Each type of motivation insertion, as well as the control, was performed twice.

To conclude, although the p-value may not be low enough to indicate strong evidence, the data shows that the intrinsic motivation and associated heart rates generally correlate with higher performance. Likewise, heart rate is generally lower in

the participants given intrinsic motivation. Subsequently, intrinsic motivation should be used to motivate those when performance matters.

6. Recommendations

This research associated with marksmanship served as a proxy for human learning in general. The goal of this research was to find the effects of different types of motivation on learning, and it can be assumed that results would also apply to learning in a remote environment.

1. As mentioned before, our results show that at least some form of motivation is beneficial to increasing performance. This can be viewed by the difference in shooting scores displayed in Figure 1 in which the control group's average is well below the others. As a result, we recommend finding ways to integrate motivation, intrinsic or extrinsic, within learning and training environments. By doing so, the likelihood of greater performance increases.
2. According to the final iteration scores shown in Figure 1, as well as the average for scores for each group throughout the experiment, intrinsic motivation was the most effective motivation type. Although we acknowledge that our unique motivation implementation cannot be perfectly replicated, we recommend applying some form of intrinsic motivation.
3. In Figure 2, we see that heart rate is lowest in the intrinsic motivated groups. Additionally, these intrinsically motivated groups performed the best at these lower heart rates. Thus, we recommend facilitating learning and training environments which foster a calm and comfortable environment resulting in lower heart rates.

Ultimately, our experiment showed that individuals treated with intrinsic motivation performed better and had lower heart rates, two aspects of learning which should be sought after in any learning environment for maximum success. Further research should be conducted to apply these principles in a remote environment.

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