Stefan Leon

Fall 2024

Prof. Thomas Lennie

Psychology Senior Thesis

Should You Try Harder? – the Relationship Between Cognitive Effort and Performance, as Mediated by Perceived Difficulty

**Abstract**

While common sense would often have us believe that trying harder leads to better results, the connection between the two has been tenuous within the relevant literature. This paper investigates the connection between cognitive effort and task performance, by manipulating perceived task difficulty. The study tracked self-reported measures of gaming frequency, self-efficacy, Need for Cognition and various perceptions towards the task, including perceived challenge, positive affect, negative affect and tension. These measures were analyzed in relation to perceived difficulty and performance on a reaction-time task – the Google Chrome Dino game. Data analysis showed a statistically significant interaction effect of gaming frequency and perceived difficulty on performance: higher performance scores were associated with lower perceived difficulty, in low gaming frequency individuals, and conversely associated with higher perceived difficulty in high gaming frequency individuals. No statistically significant relationships were observed between perceived difficulty and performance, or Need for Cognition and performance, contradicting previous research in the field. These findings suggest that environmental factors may be more important than personality factors in determining the impact of perceived difficulty on performance; in particular, the results indicate that familiarity with a skillset may have a more impactful role in determining the effectiveness of exerted cognitive effort than Need for Cognition and other personal differences. Future research would benefit from exploring the generalizability of these findings, especially within different contexts and larger sample sizes, to more clearly assess the implications for task performance and work strategies.

**Introduction**

Common wisdom would dictate that a key component of performing better is trying harder: “go the extra mile,” “give 110%” and “no pain, no gain” are all popular idioms that one might expect to hear as advice for performing better. But scientifically, the link between trying harder – characterized by conscious, willful effort – and performing better is less clear. In this paper, I will be conducting a literature review of papers dealing with similar subjects, in an attempt to better understand the relationship between effort and performance. Particularly, I will be limiting the scope of this paper to the cognitive realm – I will look specifically into the link between cognitive effort and cognitive performance.

**Cognitive Effort**

Cognitive Effort as a construct is easier to conjure up than define; at an intuitive level, “effort” implies a mentally costly and taxing activity – one might imagine concentrating on a tedious and complicated lecture as effortful, while paying attention to a stand-up routine as effortless. This distinction could be explained by the difference between the mental resources required to complete each task. These mental resources also have biological implications, too: blood glucose levels, particularly, have been linked to engagement and performance on challenging cognitive tasks, suggesting that cognitive effort taps into and depletes our energy reserves (Fairclough & Houston, 2004).

It has long been established that people are sensitive to the costs and benefits associated with energy expenditure, as evidenced by the multitudes of decision-making strategies people employ (Payne et al., 1988). In the cognitive realm, the very existence of mental heuristics – as faster, less costly alternatives to decision-making – as well as the general association of effortful experiences with negative affect suggests that people have a tendency to minimize this cost, down to the lowest-effort point where the task can still be completed, to a subjectively satisfying degree (Garbarino & Edell, 1997).

One important consideration should be given to personality differences: according to Cacioppo & Petty (1982), there are people who, instead of exhibiting this aversive tendency, actively seek out cognitively challenging tasks. This sort of intrinsic motivation – known as Need for Cognition – can make cognitive effort seem like its own reward, making people more likely to expend larger amounts of it, instead (Sandra & Otto, 2018). It is important to note that while this motivational factor is moderately correlated with cognitive ability, the former does not necessarily depend on the latter, and it continues to predict behavior even when cognitive ability is controlled for (Petty et al., 2013).

Seeing how effort is so strongly linked with a mental cost-benefit analysis of the resources needed for a task, it would make sense to look to economics – and particularly neuroeconomics – for a formal definition of cognitive effort. Westbrook & Braver (2015) define it broadly as the conscious exertion of cognitive control and attention, that is primarily – but not exclusively – determined by difficulty. Breaking this definition down further shows us several constructs that should be considered, in order to properly understand cognitive effort: cognitive control, attention, and difficulty.

***Cognitive Control***

Cognitive control, as a construct, has received a lot more attention: we can roughly understand it as one’s ability to apply their acquired knowledge and understanding of the world, in order to influence one’s own actions towards their goals (Hammond & Summers, 1972). Essentially, cognitive control serves to mediate the relationship between knowledge and performance, through people’s ability to apply that knowledge in their own lives. This accounts for much of the cognitive effort generally expended in most tasks, according to Westbrook & Braver (2015): the more complex a task is, the more control one needs to exert over their approach to properly complete the task, and consequently, the more effortful these tasks feel.

However, one notable exception comes in the form of “flow” states: these are generally characterized by a sense of effortless control over one’s ability to carry out a task (Nakamura & Csikszentmihalyi, 2014). This phenomenon complicates the assertion that the exertion of cognitive control necessarily carries with it cognitive effort; furthermore, such states can also affect people’s aversion to the costs of tasks we would generally consider effortful, motivating some to actively seek out challenging tasks, instead (Sayalı et al., 2023). The relationship between cognitive effort and flow states is not clear, however, and would require further research to properly piece apart.

***Attention***

Attention is often treated as the main resource expended during the active exertion of cognitive control: in order to maintain focus on a task for prolonged periods of time, one must direct more and more attention towards that particular task (Kaplan & Berman, 2010). Consequently, as more attentional resources are recruited for a task, there are fewer mental resources available to dedicate to subsequent tasks, thus impacting one’s performance on them. These effects have been referred to in relevant literature as *cognitive fatigue* (Westbrook & Braver, 2015) and *ego depletion* (Garrison et al., 2019), and help highlight the relationship between effort and attention: the more effortful a task is perceived to be, the more attention one will need to allocate to it.

***Difficulty***

Difficulty is one of the main factors affecting the degree of cognitive effort one exerts in solving a particular task. Westbrook & Braver’s (2015) definition acknowledges it as the primary determinant of effort, but the authors draw a distinction between different types of tasks: “resource-limited” tasks – i.e. tasks where performance depends on the degree to which one allocates resources towards them – tend to be perceived as difficult and effortful; “data-limited” tasks – i.e. tasks where the quality of the task data constitutes a bottleneck, such that further allocating resources to it would not impact performance – are perceived as difficult, but not effortful (p. 396).

**Performance**

Generally, cognitive effort is positively correlated to performance: greater cognitive effort usually signals a greater degree of engagement with a task, and thus a greater degree of cognitive control exerted as part of one’s interaction with the task; it also tends to vary alongside the attentional depletion effects previously discussed (Westbrook & Braver, 2015). However, this does not necessarily imply that greater cognitive effort is always necessary for performance: Mandrick et al. (2016) discuss the concept of *cognitive effectiveness*, as a measure for the appropriate and effective recruitment of mental resources to complete a task. Under situations of high stress and mental workload, people may not be able to properly employ the resources conjured up, lowering the ratio between performance to exerted cognitive effort; essentially, effort would increase faster than performance would, leading to a more intensive experience of effort, for a lesser improvement in performance.

This becomes especially relevant when you consider the role of difficulty in this equation. There is evidence to suggest that task difficulty can make one more susceptible to the effects of stress: Robinson et al. (2013) propose that a sufficiently difficult task – i.e. a task that can fully occupy one’s attention – coupled with a stressful environment can increase the amount of attentional resources one can recruit, thus leading to better performance on cognitive tasks; Mandrick et al. (2016) found that higher levels of stress – measured via working memory load – translated into increased perceived task difficulty and lower performance on cognitive tasks. While these studies disagree on the interaction effect of difficulty and stress on performance, they agree on the fact that higher task difficulty correlates with an increase in cognitive effort.

A possible explanation for these ambiguous results lies in considering cognitive effectiveness: if the increase in cognitive effort correlated with an objective increase in difficulty – due to stressful conditions increasing the real amount of resources needed for completing a task – then an increase in effort would lead to a proportionate increase in performance; however, if the increase in cognitive effort can be accounted for only by an increase in *perceived difficulty* – due to an erroneous, stress-induced reassessment of the task’s requirements – then the increase in effort would instead lead to a disproportionate increase in performance, which might be nullified altogether by the increased rate of cognitive depletion effects. In other words, whether the increase in effort is motivated by a real or perceived increase in difficulty might be able to account for the different relationships observed between cognitive effort and performance.

There has been some research into the effects of perceived difficulty on performance: Scasserra (2008) tested whether people would perform worse when told the task they were about to complete was more difficult, and found this hypothesis to be supported – using a repeated-measures ANOVA (*F*(1) = 10.42, p < 0.05); Li et al. (2007) tested participants on an object manipulation task, and similarly found that perceived task difficulty was negatively correlated with performance – using Spearman correlations (*r* = –0.36, p < 0.003) – alongside markers of self-efficacy – again, using Spearman correlations (*r* = –0.62, p < 0.0001); Aljamal et al. (2019) tested medical students under similar conditions, and instead found that self-efficacy and performance had opposite – negative (lower perceived difficulty group: M = 6.2; higher perceived difficulty group: M’ = 4.2; p = 0.0009) and positive (lower perceived difficulty group success rate = 45%, higher perceived difficulty group success rate = 85%; p = 0.02), respectively – statistical relations to perceived difficulty. The fact that the first two studies found perceived difficulty to be inversely correlated with performance mirrors the previously discussed result ambiguity; one interesting detail is that Aljamal et al.’s study is the only one to include mentions of referential groups – their manipulation of perceived difficulty was done by prompting them with either “90% of your peers completed the task in less than 5 minutes” or “10% of your peers completed the task in less than 5 minutes” (p. 194). There is research to suggest that a self-presentational desire, as prompted by an opportunity to outperform others, tends to increase overall task performance (Burger, 1987; Senko & Harackiewicz, 2005); thus, the presence or lack of social stakes might account for the disagreement and ambiguity in the previously mentioned studies on perceived difficulty.

One last factor we should consider is self-efficacy. As a construct, self-efficacy can be defined as someone’s judgement of whether they have the capacity to achieve a certain result or complete a certain task (Bandura, 1982). This clearly comes into play when we talk about people’s relationship with tasks they believe to be difficult; and as we have covered, reports of self-efficacy tend to decrease as the perceived difficulty of a task increases (Scasserra, 2008; Li et al., 2007; Aljamal et al., 2019). Nuutila et al. (2021) further investigated this and found particularly strong negative correlations between perceived difficulty and self-efficacy (*r* = –0.48, p < 0.001) – in addition to a weaker, but similarly significant negative correlation between interest and perceived difficulty (*r* = –0.14, p < 0.001) – and particularly strong positive correlations between self-efficacy and interest (*r* = 0.44, p < 0.001). This last finding is especially promising, as interest exerts a considerable influence on cognitive effort, by lowering the perceived costs of effort, and weakening people’s tendency to avoid exerting effort (Song et al., 2019). Further research into the link between perceived difficulty and interest might be worthwhile, considering the meaningful potential implications for both cognitive effort and performance.

**Research Hypotheses**

From the literature review above, there are a few glaring blind spots that would greatly benefit from additional research. Particularly, the link between perceived difficulty, cognitive effort and performance seems particularly fruitful to me. Manipulating and testing the effects of perceived difficulty differences might offer additional insight into (1) whether this increase truly leads to an increase in perceived effort, (2) whether an increase in perceived difficulty – and by proxy an increase in effort, under such circumstances – correlates with an increase or decrease in performance, and (3) whether the – generally negative – affect associated with increased cognitive effort changes with one’s perception of difficulty.

The following hypothesis naturally follows the first research question:

1. An increase in perceived difficulty will lead to an increase in perceived effort.

For testing the second research question, there is a little more nuance to be employed in formulating the hypotheses:

1. An increase in perceived difficulty will lead to a decrease in performance, in individuals with low Need for Cognition motivation.
2. An increase in perceived difficulty will lead to an increase in performance, in individuals with high Need for Cognition motivation.

As we have previously covered, performance and perceived difficulty have been observed to have a negative correlation, in studies that do not involve social reference groups and a chance to outperform others; since the present experiment does not include such variables within its design, I would lean towards predicting a negative statistical relationship as well. However, Cacioppo & Petty’s (1982), Need for Cognition scale has been shown to flip the traditional aversion to cognitive effort, and as such, I am also predicting that it will have a similar effect in my research as well; I am predicting that it will instead flip the relationship between perceived difficulty and performance, making people high in Need for Cognition perform better when dealing with a task they perceive to be more difficult.

There is no explicit prediction for the third research question; therefore, I will assume a certain degree of transitivity between perceived difficulty, self-efficacy and interest, and test it through the following hypotheses:

1. An increase in perceived difficulty will lead to a decrease in self-efficacy.
2. An increase in perceived difficulty will lead to a decrease in interest in the task.

Considering the evidence for self-efficacy and interest varying together, I predict that they will both vary in similar directions, as perceived difficulty changes.

**Methods**

***Participants****.*The study recruited a sample of 143 participants via an online survey, hosted on the Qualtrics platform; 76 of these participants were excluded from the final analysis after dropping out before completing the survey. The final sample (n=67) was mostly comprised of undergraduate college students (age 21.5 ± 3.96): 53.7% were men (n=36), 41.8% were women (n=28), 3% were non-binary (n=2). The participants were also asked about the number of days on with which they played video games during the past month: 35.8% played on less than one day (n=24), 17.9% played on 1-5 days (n=12), 7.5% played on 6-10 days (n=5), 11.9% played on 11-15 days (n=8), 6% played on 16-20 days (n=4) and 20.9% played on more than 20 days (n=14). Similarly, they were also asked about their familiarity with the dino game they were about to play: all of the participants had played the game before, with 16.4% of them (n=11) having played it recently.

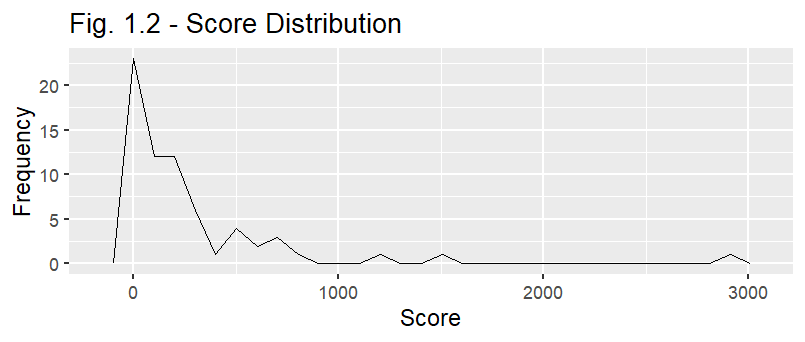
***Task Design*.** The participants were randomly assigned to one of two groups: “very hard” or “very easy.” They were informed of this assignment – albeit believing to have been assigned to one of four experimental groups, ranging from “very easy” to “very hard,” in order to maximize the effects of perceived difficulty – and then asked to play the Google Chrome Dino game, as provided by thecodepost (n.d.). This game was chosen for its simple design – it functions similarly to a reaction time cognitive task – and for its pervasiveness within digital culture, which serves to moderate the impact of previous experience with the game. Furthermore, it enables the survey to be conducted on any device, increasing the potential number of participants that can be recruited. All participants were subject to the same version of the game. They were allowed to play the game as much as they needed to familiarize themselves with the rules and controls, before being asked to play it once and record their score. The final sample contained 33 participants assigned to the “very easy” condition (referred to as “group easy”) and 34 participants assigned to the “very hard” condition (referred to as “group hard”).

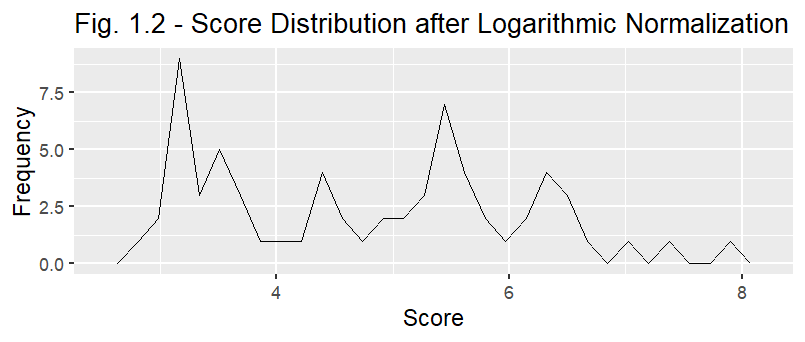
***Post-Task Questionnaire*.** After completing the experimental task, the participants were asked to answer questions corresponding to the Positive Affect, Negative Affect, Challenge, Tension/Annoyance components of the Game Experience Questionnaire (IJsselsteijn, 2013), followed by questions based off of Allan’s (2010) thesis on self-efficacy in the gaming domain, and finally a section corresponding to 14 questions from Cacioppo et al.’s (1984) shortened Need for Cognition assessment questionnaire. All of these were scored on a 7-point Likert scale, representing degrees of agreement between “Strongly Disagree” – at (1) – and “Strongly Agree” – at (7). Scoring instructions for the Game Experience Questionnaire components and for the Need for Cognition scale are detailed within their respective papers. The self-efficacy measure was computed via a simple sum; the first question was reverse scored, while all the others were scored normally. The particular questions used in the full questionnaire are available in Appendix A.

**Results**

The data analysis relied on t-tests, ANOVAs and linear regression models to test experimental hypotheses. All processes of analysis were completed using R; particular scripts used in the testing and processing of the dataset are available in Appendix B.

Initial analysis of the participants’ scores showed a significant positive skew (fig. 1.1). In order to comply with ANOVA assumptions for hypothesis testing, the data was transformed using a natural logarithmic function (), thus bringing it closer to a normal distribution (the skewness value changed from 3.95 to 0.22), as shown in figure 1.2. Many psychological phenomena are understood in terms of proportional rather than absolute differences; for example, a 10-point difference on a scale might be more meaningful at lower scores than at higher scores. Logarithmic transformation preserves proportional relationships, making the analysis more relevant to the underlying phenomenon. In this case, the data represents the highest score obtained by participants when playing the Chrome Dino Game. As such, it represents a clear example of proportional differences, and a transformation is unlikely to affect the interpretation drastically.





A t-test analyzing gender differences found that no statistically significant differences (men: M = 5.09, SD = 1.36; women: M’ = 4.49, SD’ = 1.16; *t*(61.46) = 1.88, p = 0.07). To test hypothesis (1), I used a t-test to analyze the effect of perceived difficulty on challenge – operationalized by using the Challenge component of IJsselsteijn’s (2013) Game Experience Questionnaire; this showed a positive, but statistically not significant effect (easy group: M = 3.25, SD = 1.35; hard group: M’ = 3.55, SD’ = 1.24; *t*(64.14) = 0.96, p = 0.339). I conducted a follow-up independent-measures ANOVA to check whether accounting for gaming frequency would draw out hidden effects, but this showed no statistically significant results, either (*F*(1, 63) = 3.51e-03, p = 0.953).

An initial comparison of scores across experimental conditions (fig. 2) shows the mean score in the very easy group to be higher than the one in the very hard group. However, a follow-up t-test found this difference to be statistically not significant (group easy: M = 4.72, SD = 1.16; group hard: M’ = 4.81, SD’ = 1.45; *t*(62.84) = –0.26, p = 0.8).

A graph with different colored squares

Description automatically generated

In order to draw out the potential effects of the Need for Cognition (NfC), participants were divided into two categories (low NfC and high NfC) by comparing their computed NfC score to the mean score of the sample (M = 14.72). The final distribution had 35 participants identified as low NfC and 32 identified as high NfC. The participants’ NfC scores were unimodal (fig. 3.1) and roughly normally distributed (skewness = 0.22). An independent-measures ANOVA was computed to test hypotheses (2) and (3) – whether an interaction effect of low/high NfC and perceived difficulty would affect scores – and found no statistically significant effect (*F*(1, 63) = 0.44, p = 0.511), even when further accounting for the variance across the 6 gaming frequency categories (*F*(1, 59) = 0.35, p = 0.556).

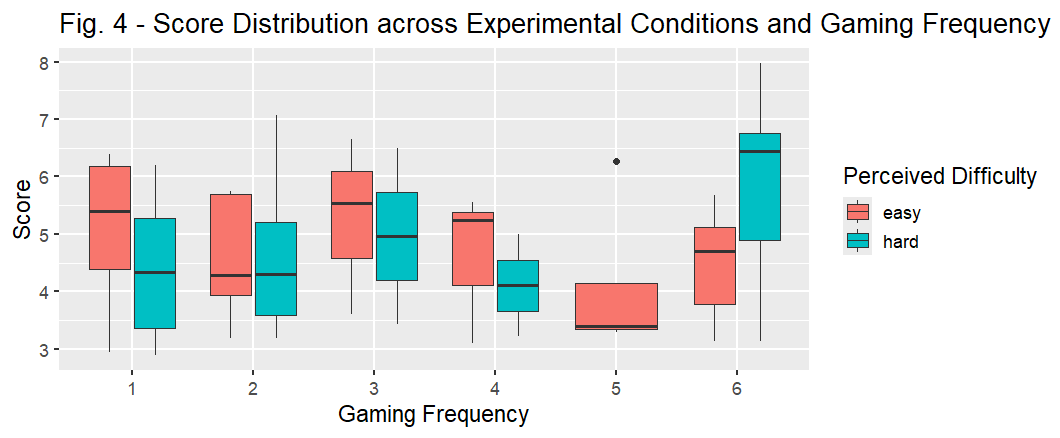
A graph with a line graph

Description automatically generated

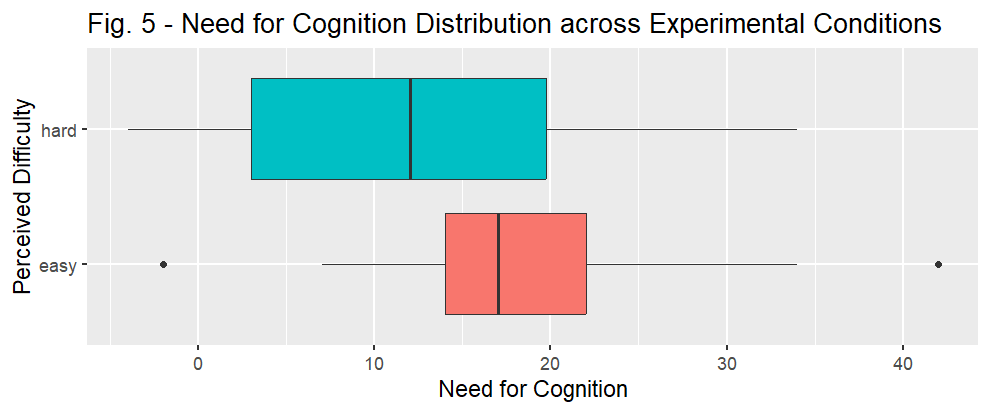
A graph with colored squares and black lines

Description automatically generated

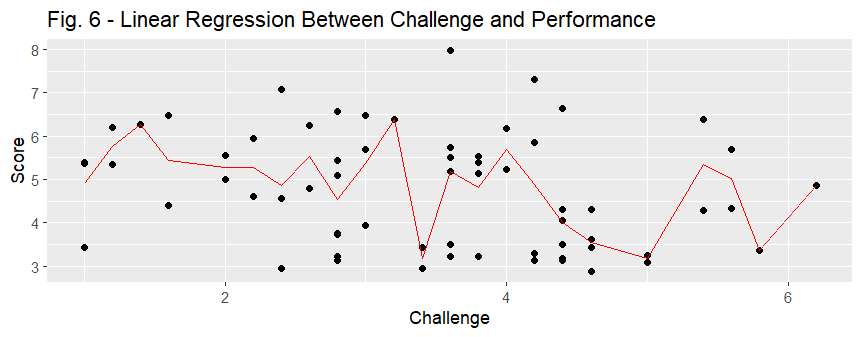
An interesting interaction effect was observed when accounting for frequency in the relationship between perceived difficulty and score: the interaction effect was statistically significant, accounting for a medium proportion of the variance (*F*(1, 63) = 5.78, p = 0.019)), as computed by a 2x6 independent-measures ANOVA using the perceived difficulty and gaming frequency, respectively, as factors.. The largest differences can be observed at the extremes of gaming frequency (fig. 4), in people who either played no video games during the past month and those that played video games nearly every day. The relationship between perceived difficulty and performance is negative at the lower end of frequency (group easy: M = 5.07, SD = 1.28; group hard: M’ = 4.44, SD’ = 1.12) and positive at the higher end of it (group easy: M = 4.49, SD = 0.99; group hard: M’ = 5.82, SD’ = 1.78). Follow-up tests were conducted to test whether any main effects could be observed, either within particular frequency groups or withing experimental conditions: there was a statistically significant effect of gaming frequency on performance in conditions of harder perceived difficulty, as shown by an independent-measures ANOVA (*F*(1, 32) = 4.87, p = 0.035), but there was no statistically significant effect in conditions of easier perceived difficulty (*F*(1, 31) = 1.41, p = 0.244); there were no statistically significant results gleamed form running a series of t-tests to investigate the effect of perceived difficulty on performance, within particular gaming frequency groups.



Another unexpected finding was a statistically significant relationship between NfC scores and perceived difficulty (fig. 5). Participants in the easy group scored significantly higher on the NfC scale than the ones in the hard group (group easy: M = 17.73, SD = 8.27; group hard: M’ = 11.79, SD’ = 10.3; p = 0.011). A follow-up independent-measures ANOVA was used to test the connection between NfC scores and task scores showed no statistically significant relationship between the two (*F*(1, 65) = 2.10e-03, p = 0.964). A linear regression model was computed to test whether NfC scores would be predictive of perceived challenge, but no statistically significant results were found (*R2* = 6.59e-06, *F*(1, 65) = 4.28e-04, *β* = –3.41e-04, p = 0.984).



A linear regression model was used to test whether a subjective experience of challenge – as measured by the Challenge component of the Game Experience Questionnaire – would predict performance. The regression was statistically significant (*R2* = 0.07, *F*(1, 65) = 4.72, p = 0.033), finding that challenge negatively predicted performance (*β* = –0.26).



Against hypothesis (4), perceived difficulty did not influence self-efficacy to a statistically significant degree (group easy: M = 16.58, SD = 6.07; group hard: M’ = 16.62, SD’ = 3.34; p = 0.978). However, self-efficacy was found to positively predict performance (*R2* = 0.10, *F*(1, 65) = 6.96, *β* = 0.31, p = 0.01), while gaming frequency was found to positively predict self-efficacy to a statistically significant degree (*R2* = 0.17, *F*(1, 65) = 13.09, *β* = 1.28, p < 0.001).

A series of t-tests were performed to test the effect of perceived difficulty on Gaming Experience Questionnaire components pertaining to interest in the task, testing hypothesis (5): Positive Affect (group easy: M = 4.47, SD = 1.37; group hard: M’ = 4.45, SD’ = 1.26; *t*(64.16) = 0.08, p = 0.937), Negative Affect (group easy: M = 3.11, SD = 1.09; group hard: M’ = 3.40, SD’ = 1.13; *t*(65.00) = –1.07, p = 0.287) and Tension/Annoyance (group easy: M = 3.29, SD = 1.55; group hard: M’ = 3.86, SD’ = 1.74; *t*(64.53) = –1.42, p = 0.161). No statistically significant results were observed. Follow-up independent-measures ANOVAs were computed to test for interaction effects between gaming frequency and perceived difficulty – in the case of Positive Affect (*F*(1, 63) = 2.04, p = 0.159), Negative Affect (*F*(1, 63) = 0.97, p = 0.329) and Tension/Annoyance (*F*(1, 63) = 0.08, p = 0.774), respectively – but no further statistically significant results were observed.

A correlation matrix was used to further analyze the relationship between performance score, Positive Affect, Negative Affect and Tension/Annoyance, using Pearson’s correlation coefficient (fig. 7). There was a strong negative correlation observed between score and Tension/Annoyance (*r* = –0.53), and a moderate positive correlation between score and Positive Affect (*r* = 0.33). There was also a notable strong negative correlation between Positive Affect and Negative Affect (*r* = –0.48) and Tension/Annoyance (*r* = –0.53), respectively. Negative Affect and Tension/Annoyance were also found to be strongly correlated (*r* = 0.49). In addition, a linear regression model was used to test whether performance would be predictive of any of these components. The linear regression was statistically significant in the case of Positive Affect (*R2* = 0.11, *F*(1, 65) = 7.86, *β* = 0.33, p = 0.007) and Tension/Annoyance (*R2* = 0.29, *F*(1, 65) = 25.95, *β* = -0.68 p < 0.001); thus, performance scores positively predicted Positive Affect and negatively predicted Tension/Annoyance.

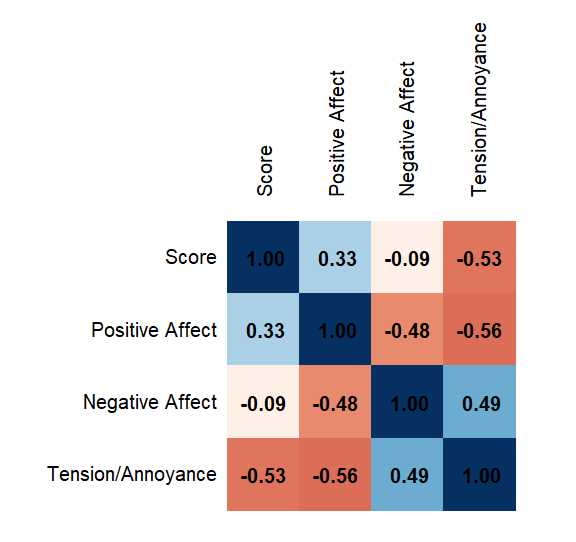


Fig. 7 – Score and Interest Correlation Matrix

**Discussion**

This study found all hypotheses proposed to be largely unsupported. For the first hypothesis, an increase in perceived difficulty did not lead to an increase in perceived challenge, and may therefore not have warranted an increase in cognitive effort. This might suggest that the experimental manipulation employed might have been ineffective to some degree. There are several explanations as to why: I received reports from some participants that the task sometimes seemed impossible, due to device and connectivity limitations; this perception might have turned the task into a data-limited one, rather than a resource-limited one, and consequently – as per Westbrook & Braver (2015) – would not require the recruitment of more cognitive resources via cognitive effort. This is made all the more likely by the fact that perceived challenge was predictive of performance, while perceived difficulty was not, suggesting again that the test employed was not able to completely capture the relationship between perceived difficulty and performance.

The second and third hypotheses were also unsupported. The variance in Need for Cognition scores and perceived difficulty did not seem to account for the variance in performance scores, or in perceived challenge, despite findings suggesting otherwise (Petty et al., 2013; Sandra & Otto, 2018). Instead, we also found that the participants’ self-perception of their Need for Cognition was also influenced by the perceived difficulty of the task, with lower perceived difficulty leading to higher reported Need for Cognition. This might be explained as people being more willing to engage in further cognitive tasks after being exposed to a seemingly easy one, rather than a hard one. Notably, this relationship was not mirrored by one between scores and Need for Cognition, further suggesting that it was indeed difficulty, and not performance, that produced this effect.

The lack of support for hypotheses (2) and (3) also points towards environmental factors being more relevant than personality ones – at least in the case of this experimental task. Indeed, gaming frequency produced an effect similar to one we had hypothesized for Need for Cognition: in people who played video games nearly everyday for the past month, performance scores were higher when perceived difficulty was higher, while in people who played no video games for the past month, performance scores were lower when perceived difficulty was higher. This finding suggests that experience with skills relevant to a task can serve to flip the normal aversion to cognitive effort, instead of Need for Cognition: people highly familiar with this skillset may be more likely to see the harder task as a welcome challenge, leading to increased performance, while people unfamiliar with the skillset might instead perceive the harder task as one that is nearly impossible to do well in, thus lessening the impact of the additional cognitive resources recruited and leading to decreased performance. This idea would also suggest that skill experience might govern the relationship between cognitive effort and performance to a higher extent than Need for Cognition.

Hypothesis (4) was once again unsupported. Perceived difficulty had no significant effect on reported self-efficacy; instead, higher self-efficacy was predicted by higher gaming frequency. In support of previous research (Aljamal et al., 2019; Li et al., 2007; Nuutila et al., 2021; Scasserra, 2008), however, self-efficacy was predictive of higher performance scores.

For hypothesis (5), none of the components used to measure interest were significantly accounted for by perceived difficulty. However, there were significant correlations and linear regressions between performance scores and some of these facets: scores positively predicted positive affect and negatively predicted tension/annoyance, which suggests a connection between performance and interest, even though no relationship between perceived difficulty and interest could be observed.

Additionally, this study found no significant relationship between perceived difficulty – by itself – and performance. This goes against previously discussed findings (Aljamal et al., 2019; Scasserra, 2008; Senko & Harackiewicz, 2005) and indicates once again that we would require further research before we could decisively talk about this link.

**Limitations**

The participants recruited by the study were predominantly undergraduate college students, thus making generalizing these results to a wider population complicated, for a variety of reasons. Firstly, the age of the participants skews younger: the findings may not hold true for populations of all ages, especially considering that previous research has shown that cognitive effort tends to exert a heavier toll on older individuals, in turn making them less likely to engage with more difficult tasks (Ennis et al., 2013). Secondly, college-educated participants tend to perform better on measures of cognitive effort (Nijdam-Jones et al., 2019) – which would likely also correlate with higher scores on the Need for Cognition scale (Petty et al., 2013) – making it harder to predict whether a test involving less educated population samples would also exhibit the same results.

This study maximized the recruitment of potential respondents, and so made some sacrifices in terms of the control it exerted over the environmental factors affecting the participants at the time of the survey. Many potentially relevant physical factors could not be controlled for: the total time spent on completing the survey, the time spent in the practice stage of the game before proceeding to the task section, the time of day when the survey was completed, the degree to which the room they were in was silent or noisy, just to name a few. Furthermore, in order to maximize the potential response rate, the post-task questionnaire was kept as minimal as possible, and other psychological factors that might have been important – mood, stress levels etc. – could not be tracked. Future research might benefit from studies ran within more controlled environments, and from tracking a more varied set of psychological factors.

One additional variable not tracked by this study was the degree to which participants felt an intrinsic motivation to perform well on the task – this aspect is partly captured by Need for Cognition, but to a much lesser extent. Research has found evidence that the personal importance of a task may serve to increase one’s desire to exert cognitive effort and engage with a more cognitively demanding task, thus mediating the relationship between difficulty and performance (Ennis et al., 2013; Petty et al., 2013). The task at hand was not considered appropriate for testing this variable – as it is highly unlikely people would assign a high degree of importance to performing well on it – and was therefore not considered when making the questionnaire.

Additionally, the survey was designed so it could be completed on both computers and mobile devices; however, reports from participants indicate that the difficulty of the experimental task was not static across devices, with mobile devices being more susceptible to input lag and connectivity issues, likely leading to lower scores – as well as intensified frustration, which might partially explain the study’s high drop-out rate – for some of the participants.

The task employed in the experiment – the Chrome Dino game – also involves a few specific considerations. While it is fundamentally similar to reaction-time cognitive task in terms of the cognitive resources required, the gamified nature of the task makes it more difficult to generalize these results to non-gaming contexts. As previously discussed, it is unlikely that the task would be perceived as particularly meaningful, and thus may not be representative of a great deal of day-to-day or work-related activities. Future research might benefit from using different types of tests and looking at these relationships within different contexts.

Finally, despite the focus on maximizing accessibility and response rates, this study suffers from issues related to small sample sizes. Due to the between-subjects design of the experiment, further fragmentation of the sample for statistical analysis purposes became problematic, as it left me with exceedingly small numbers to consider per category. It is unsurprising, for example, that the greatest differences in the interaction effect between perceived difficulty and gaming frequency on performance scores was found at the opposite ends of the gaming frequency spectrum, given that those two ends ended up with the largest samples to consider. Similar follow-up studies looking at larger sample sizes would greatly benefit our understanding of the phenomena discussed in this paper.

**References**

Aljamal, Y., Prabhakar, N., Saleem, H., & Farley, D. R. (2019). Can the Perceived Difficulty of a Task Enhance Trainee Performance? *Journal of Surgical Education*, *76*(6), e193–e198. <https://doi.org/10.1016/j.jsurg.2019.08.005>

Allan, J. D. (2010). *An Introduction To Video Game Self-Efficacy* [Thesis]. <https://csuchico-dspace.calstate.edu/bitstream/handle/10211.3/10211.4_257/11%2015%202010%20Justin%20Allan.pdf?sequence=1>

Bandura, A. (1982). Self-efficacy mechanism in human agency. *American Psychologist*, *37*(2), 122–147. <https://doi.org/10.1037/0003-066X.37.2.122>

Burger, J. M. (1987). Increased performance with increased personal control: A self-presentation interpretation. *Journal of Experimental Social Psychology*, *23*(4), 350–360. <https://doi.org/10.1016/0022-1031(87)90046-1>

Cacioppo, J. T., & Petty, R. E. (1982). The need for cognition. *Journal of Personality and Social Psychology*, *42*(1), 116–131. <https://doi.org/10.1037/0022-3514.42.1.116>

Cacioppo, J. T., Petty, R. E., & Feng Kao, C. (1984). The Efficient Assessment of Need for Cognition. *Journal of Personality Assessment*, *48*(3), 306–307. <https://doi.org/10.1207/s15327752jpa4803_13>

Ennis, G. E., Hess, T. M., & Smith, B. T. (2013). The impact of age and motivation on cognitive effort: Implications for cognitive engagement in older adulthood. *Psychology and Aging*, *28*(2), 495–504. <https://doi.org/10.1037/a0031255>

Fairclough, S. H., & Houston, K. (2004). A metabolic measure of mental effort. *Biological Psychology*, *66*(2), 177–190. <https://doi.org/10.1016/j.biopsycho.2003.10.001>

Garbarino, Ellen C., & Edell, Julie A. (1997). Cognitive Effort, Affect, and Choice. *Journal of Consumer Research*, *24*(2), 147–158. <https://doi.org/10.1086/209500>

Garrison, K. E., Finley, A. J., & Schmeichel, B. J. (2019). Ego Depletion Reduces Attention Control: Evidence From Two High-Powered Preregistered Experiments. *Personality & Social Psychology Bulletin*, *45*(5), 728–739. <https://doi.org/10.1177/0146167218796473>

Hammond, K. R., & Summers, D. A. (1972). Cognitive control. *Psychological Review*, *79*(1), 58–67. <https://doi.org/10.1037/h0031851>

IJsselsteijn, W. A., de Kort, Y. A. W., & Poels, K. (2013). *The Game Experience Questionnaire*. Technische Universiteit Eindhoven.

Kaplan, S., & Berman, M. G. (2010). Directed Attention as a Common Resource for Executive Functioning and Self-Regulation. *Perspectives on Psychological Science*, *5*(1), 43–57. <https://doi.org/10.1177/1745691609356784>

Li, W., Lee, A., & Solmon, M. (2007). The role of perceptions of task difficulty in relation to self-perceptions of ability, intrinsic value, attainment value, and performance. *European Physical Education Review*, *13*(3), 301–318. <https://doi.org/10.1177/1356336x07081797>

Mandrick, K., Peysakhovich, V., Rémy, F., Lepron, E., & Causse, M. (2016). Neural and psychophysiological correlates of human performance under stress and high mental workload. *Biological Psychology*, *121*, 62–73. <https://doi.org/10.1016/j.biopsycho.2016.10.002>

Nakamura, J., & Csikszentmihalyi, M. (2014). The Concept of Flow. In *Flow and the Foundations of Positive Psychology* (pp. 239–263). Springer, Dordrecht. <https://doi.org/10.1007/978-94-017-9088-8_16>

Nijdam-Jones, A., Rivera, D., Rosenfeld, B., & Arango-Lasprilla, J. C. (2019). The effect of literacy and culture on cognitive effort test performance: An examination of the Test of Memory Malingering in Colombia. *Journal of Clinical and Experimental Neuropsychology*, *41*(10), 1015–1023. https://doi.org/10.1080/13803395.2019.1644294

Nuutila, K., Tapola, A., Tuominen, H., Molnár, G., & Niemivirta, M. (2021). Mutual relationships between the levels of and changes in interest, self-efficacy, and perceived difficulty during task engagement. *Learning and Individual Differences*, *92*, 102090. <https://doi.org/10.1016/j.lindif.2021.102090>

Payne, J. W., Bettman, J. R., & Johnson, E. J. (1988). Adaptive strategy selection in decision making. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *14*(3), 534–552. <https://doi.org/10.1037/0278-7393.14.3.534>

Petty, R. E., Briñol, P., Loersch, C., & McCaslin, M. J. (2013). The Need for Cognition. In M. R. Leary & R. H. Hoyle (Eds.), *Handbook of Individual Differences in Social Behavior*. Guilford Publications.

Robinson, O. J., Vytal, K., Cornwell, B. R., & Grillon, C. (2013). The impact of anxiety upon cognition: Perspectives from human threat of shock studies. *Frontiers in Human Neuroscience*, *7*(203). <https://doi.org/10.3389/fnhum.2013.00203>

Sandra, D. A., & Otto, A. R. (2018). Cognitive capacity limitations and Need for Cognition differentially predict reward-induced cognitive effort expenditure. *Cognition*, *172*, 101–106. <https://doi.org/10.1016/j.cognition.2017.12.004>

Sayalı, C., Heling, E., & Cools, R. (2023). Learning progress mediates the link between cognitive effort and task engagement. *Cognition*, *236*, 105418. <https://doi.org/10.1016/j.cognition.2023.105418>

Scasserra, D. (2008). *The influence of perceived task difficulty on task performance* [Thesis]. <https://rdw.rowan.edu/etd/756/>

Senko, C., & Harackiewicz, J. M. (2005). Achievement Goals, Task Performance, and Interest: Why Perceived Goal Difficulty Matters. *Personality and Social Psychology Bulletin*, *31*(12), 1739–1753. <https://doi.org/10.1177/0146167205281128>

Song, J., Kim, S., & Bong, M. (2019). The More Interest, the Less Effort Cost Perception and Effort Avoidance. *Frontiers in Psychology*, *10*. <https://doi.org/10.3389/fpsyg.2019.02146>

thecodepost. (n.d.). *CodePen Embed - Dinosaur Game Chrome*. Codepen.io. Retrieved May 5, 2024, from <https://codepen.io/MysticReborn/embed/rygqao>

Westbrook, A., & Braver, T. S. (2015). Cognitive effort: A neuroeconomic approach. *Cognitive, Affective, & Behavioral Neuroscience*, *15*(2), 395–415. <https://doi.org/10.3758/s13415-015-0334-y>

**Appendix A – Survey Questionnaire**

**INTRODUCTION.** Thank you for your interest in participating in this research study! My name is Stefan Leon, and I am conducting a study to explore the relationship between difficulty and cognitive performance in individuals. During this study, you will be tasked with playing a game of varying difficulty to the best of your abilities, after which you will be asked to answer a series of questions regarding your habits and perceptions towards the game you just played. The purpose of this is to assess your performance, in connection to the difficulty you will be randomly assigned to.  Your participation in this study is entirely voluntary, and you may withdraw at any time without penalty. All of your responses will be anonymous and confidential and used for research purposes only. For feedback, questions or concerns, please do not hesitate to contact us at stl200@aubg.edu and tlennie@aubg.edu.

**CONSENT FOR PROCESSING OF PERSONAL DATA.** I understand that my participation in this study is entirely voluntary, and I may withdraw at any time without penalty. I also understand that my responses will be confidential, and only aggregate data will be reported in any publications resulting from this study. I have been provided with contact information for the researcher conducting this study, and I understand that I may contact them with any questions or concerns I may have. I certify that I am at least 18 years of age and that I have read and understood the information provided in this consent form. **By continuing, I agree to participate in this research study.**

**Demographics**

1 What is your age?

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

2 What is your gender?

* Male (1)
* Female (2)
* Non-binary / third gender (3)
* Prefer not to say (4)

3 During the past month, on how many days did you play video games?

* Less than 1 day (1)
* 1-5 days (2)
* 6-10 days (3)
* 11-15 days (4)
* 15-20 days (5)
* More than 20 days (6)

4 How familiar are you with the Chrome Dino game?

* I have never played this game before. (1)
* I have played this game before. (2)
* I have played this game recently. (3)

You will now be presented with a game, that you will be asked to play to the best of your ability. There are four possible versions of the game: **very easy**, **easy**, **hard**, and **very hard**. You will be randomly assigned to one of them. Please proceed whenever you are ready.

**Random Assignment – Game Easy or Game Hard**

**Game Easy**

You have been randomly assigned the **very easy** version of the game. Please take a moment to familiarize yourself with the game. Please click or press on the game screen in order to begin. Press the **SPACE bar** to jump, and try to avoid the obstacles.If you are on a mobile device, you will need to press the screen, instead.  
  
When you feel ready, press **Next** to proceed.

|  |  |
| --- | --- |
| Page Break |  |

Now, please play the game **once**, to the best of your ability. Try to avoid the obstacles and get as high a score (displayed in the upper-right side of the game screen) as you can manage.

Please record your score below.

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

|  |  |
| --- | --- |
| Page Break |  |

**Game Hard**

You have been randomly assigned the **very hard**version of the game. Please take a moment to familiarize yourself with the game. Please click or press on the game screen in order to begin. Press the **SPACE bar** to jump, and try to avoid the obstacles. If you are on a mobile device, you will need to **press** the screen, instead.  
  
When you feel ready, press **Next** to proceed.

|  |  |
| --- | --- |
| Page Break |  |

Now, please play the game **once**, to the best of your ability. Try to avoid the obstacles and get as high a score (displayed in the upper-right side of the game screen) as you can manage.

66 Please record your score below.

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

|  |  |
| --- | --- |
| Page Break |  |

**Game Experience Questionnaire**

In this section, you will be asked to indicate your level of agreement with certain statements, as they pertain to your perception of the game you just played. Please respond honestly and to the best of your knowledge. There are no right or wrong answers.

1 I felt content.

* Strongly disagree (1)
* Disagree (2)
* Somewhat disagree (3)
* Neither agree nor disagree (4)
* Somewhat agree (5)
* Agree (6)
* Strongly agree (7)

3 I thought it was fun.

* Strongly disagree (1)
* Disagree (2)
* Somewhat disagree (3)
* Neither agree nor disagree (4)
* Somewhat agree (5)
* Agree (6)
* Strongly agree (7)

4 I felt happy.

* Strongly disagree (1)
* Disagree (2)
* Somewhat disagree (3)
* Neither agree nor disagree (4)
* Somewhat agree (5)
* Agree (6)
* Strongly agree (7)

5 It put me in a bad mood.

* Strongly disagree (1)
* Disagree (2)
* Somewhat disagree (3)
* Neither agree nor disagree (4)
* Somewhat agree (5)
* Agree (6)
* Strongly agree (7)

6 I thought about other things.

* Strongly disagree (1)
* Disagree (2)
* Somewhat disagree (3)
* Neither agree nor disagree (4)
* Somewhat agree (5)
* Agree (6)
* Strongly agree (7)

7 I found it tiresome.

* Strongly disagree (1)
* Disagree (2)
* Somewhat disagree (3)
* Neither agree nor disagree (4)
* Somewhat agree (5)
* Agree (6)
* Strongly agree (7)

8 I thought it was hard.

* Strongly disagree (1)
* Disagree (2)
* Somewhat disagree (3)
* Neither agree nor disagree (4)
* Somewhat agree (5)
* Agree (6)
* Strongly agree (7)

9 I felt good.

* Strongly disagree (1)
* Disagree (2)
* Somewhat disagree (3)
* Neither agree nor disagree (4)
* Somewhat agree (5)
* Agree (6)
* Strongly agree (7)

10 I felt bored.

* Strongly disagree (1)
* Disagree (2)
* Somewhat disagree (3)
* Neither agree nor disagree (4)
* Somewhat agree (5)
* Agree (6)
* Strongly agree (7)

11 I enjoyed it.

* Strongly disagree (1)
* Disagree (2)
* Somewhat disagree (3)
* Neither agree nor disagree (4)
* Somewhat agree (5)
* Agree (6)
* Strongly agree (7)

12 I felt annoyed.

* Strongly disagree (1)
* Disagree (2)
* Somewhat disagree (3)
* Neither agree nor disagree (4)
* Somewhat agree (5)
* Agree (6)
* Strongly agree (7)

13 I felt pressured.

* Strongly disagree (1)
* Disagree (2)
* Somewhat disagree (3)
* Neither agree nor disagree (4)
* Somewhat agree (5)
* Agree (6)
* Strongly agree (7)

15 I felt irritable.

* Strongly disagree (1)
* Disagree (2)
* Somewhat disagree (3)
* Neither agree nor disagree (4)
* Somewhat agree (5)
* Agree (6)
* Strongly agree (7)

16 I felt challenged.

* Strongly disagree (1)
* Disagree (2)
* Somewhat disagree (3)
* Neither agree nor disagree (4)
* Somewhat agree (5)
* Agree (6)
* Strongly agree (7)

17 I felt frustrated.

* Strongly disagree (1)
* Disagree (2)
* Somewhat disagree (3)
* Neither agree nor disagree (4)
* Somewhat agree (5)
* Agree (6)
* Strongly agree (7)

18 I felt time pressure.

* Strongly disagree (1)
* Disagree (2)
* Somewhat disagree (3)
* Neither agree nor disagree (4)
* Somewhat agree (5)
* Agree (6)
* Strongly agree (7)

19 I had to put a lot of effort into it.

* Strongly disagree (1)
* Disagree (2)
* Somewhat disagree (3)
* Neither agree nor disagree (4)
* Somewhat agree (5)
* Agree (6)
* Strongly agree (7)

**Gaming Self-Efficacy**

In this section, you will be asked to indicate your level of agreement with certain statements, as they pertain to yourself. Please respond honestly and to the best of your knowledge. There are no right or wrong answers.

41 If I have to play a video game I’ve never played before, I already know I’m going to lose.

* Strongly disagree (1)
* Disagree (2)
* Somewhat disagree (3)
* Neither agree nor disagree (4)
* Somewhat agree (5)
* Agree (6)
* Strongly agree (7)

42 No matter how challenging the video game is, I can beat it if I try hard enough.

* Strongly disagree (1)
* Disagree (2)
* Somewhat disagree (3)
* Neither agree nor disagree (4)
* Somewhat agree (5)
* Agree (6)
* Strongly agree (7)

44 I can quickly and easily learn the buttons and controls for a new game.

* Strongly disagree (1)
* Disagree (2)
* Somewhat disagree (3)
* Neither agree nor disagree (4)
* Somewhat agree (5)
* Agree (6)
* Strongly agree (7)

45 I consider myself a gamer.

* Strongly disagree (1)
* Disagree (2)
* Somewhat disagree (3)
* Neither agree nor disagree (4)
* Somewhat agree (5)
* Agree (6)
* Strongly agree (7)

46 I enjoy playing video games.

* Strongly disagree (1)
* Disagree (2)
* Somewhat disagree (3)
* Neither agree nor disagree (4)
* Somewhat agree (5)
* Agree (6)
* Strongly agree (7)

**Need for Cognition**  
In this section, you will be asked to indicate your level of agreement with certain statements, as they pertain to yourself. Please respond honestly and to the best of your knowledge. There are no right or wrong answers.

35 I would prefer complex to simple problems.

* Strongly disagree (1)
* Disagree (2)
* Somewhat disagree (3)
* Neither agree nor disagree (4)
* Somewhat agree (5)
* Agree (6)
* Strongly agree (7)

36 I like to have the responsibility of handling a situation that reuires a lot of thinking.

* Strongly disagree (1)
* Disagree (2)
* Somewhat disagree (3)
* Neither agree nor disagree (4)
* Somewhat agree (5)
* Agree (6)
* Strongly agree (7)

37 Thinking is not my idea of fun.

* Strongly disagree (1)
* Disagree (2)
* Somewhat disagree (3)
* Neither agree nor disagree (4)
* Somewhat agree (5)
* Agree (6)
* Strongly agree (7)

48 I would rather do something that requires little thought than something that is sure to challenge my thinking abilities.

* Strongly disagree (1)
* Disagree (2)
* Somewhat disagree (3)
* Neither agree nor disagree (4)
* Somewhat agree (5)
* Agree (6)
* Strongly agree (7)

49 I try to anticipate and avoid situations where there is likely chance I will have to think in depth about something.

* Strongly disagree (1)
* Disagree (2)
* Somewhat disagree (3)
* Neither agree nor disagree (4)
* Somewhat agree (5)
* Agree (6)
* Strongly agree (7)

50 I find satisfaction in deliberating hard and for long hours.

* Strongly disagree (1)
* Disagree (2)
* Somewhat disagree (3)
* Neither agree nor disagree (4)
* Somewhat agree (5)
* Agree (6)
* Strongly agree (7)

51 I only think as hard as I have to.

* Strongly disagree (1)
* Disagree (2)
* Somewhat disagree (3)
* Neither agree nor disagree (4)
* Somewhat agree (5)
* Agree (6)
* Strongly agree (7)

52 I prefer to think about small, daily projects to long-term ones.

* Strongly disagree (1)
* Disagree (2)
* Somewhat disagree (3)
* Neither agree nor disagree (4)
* Somewhat agree (5)
* Agree (6)
* Strongly agree (7)

53 I like tasks that require little thought once I've learned them.

* Strongly disagree (1)
* Disagree (2)
* Somewhat disagree (3)
* Neither agree nor disagree (4)
* Somewhat agree (5)
* Agree (6)
* Strongly agree (7)

54 The idea of relying on thought to make my way to the top appeals to me.

* Strongly disagree (1)
* Disagree (2)
* Somewhat disagree (3)
* Neither agree nor disagree (4)
* Somewhat agree (5)
* Agree (6)
* Strongly agree (7)

55 I really enjoy a task that involves coming up with new solutions to problems.

* Strongly disagree (1)
* Disagree (2)
* Somewhat disagree (3)
* Neither agree nor disagree (4)
* Somewhat agree (5)
* Agree (6)
* Strongly agree (7)

56 Learning new ways to think doesn't excite me very much.

* Strongly disagree (1)
* Disagree (2)
* Somewhat disagree (3)
* Neither agree nor disagree (4)
* Somewhat agree (5)
* Agree (6)
* Strongly agree (7)

57 I prefer my life to be filled with puzzles that I must solve.

* Strongly disagree (1)
* Disagree (2)
* Somewhat disagree (3)
* Neither agree nor disagree (4)
* Somewhat agree (5)
* Agree (6)
* Strongly agree (7)

58 The notion of thinking abstractly is appealing to me.

* Strongly disagree (1)
* Disagree (2)
* Somewhat disagree (3)
* Neither agree nor disagree (4)
* Somewhat agree (5)
* Agree (6)
* Strongly agree (7)

**Debriefing**  
Thank you for your participation in this study! You were previously informed that the present study is looking at the relationship between difficulty and cognitive performance. The real goal of my research however, is looking at the connection between our perceptions of difficulty and performance. In reality, there is only one version of the game presented to all participants, which are only prompted with a message telling them they are playing a "very easy" or "very hard" version of the game. My hypothesis is that people will mostly perform better on tasks they perceive as easy, independently of the objective difficulty of the task. The purpose of the questions you were asked afterwards was measuring several other behavioral and cognitive tendencies that I believe will affect one's performance on the task. If you would like to be informed of the results of this test, at a later date, please contact us and we will email you the results as soon as they are available. Additionally, if you have any further feedback, questions or concerns, please do not hesitate to reach out to at stl200@aubg.edu or tlennie@aubg.edu. Thank you again for your time!

**Appendix B**

**R Script Used for Dataset Processing and Manipulation**

library (tidyverse)

num\_set <- read.csv ("C:\\Psych Senior Project Responses\\143\_num\_processed.csv")

to\_rm <- filter (num\_set, is.na(s1))

data <- anti\_join (num\_set,to\_rm)

# GEQ Scoring

data = data %>%

mutate(challenge = (g11 + g23 + g26 + g32 + g33) / 5) %>%

mutate(tension = (g22 + g24 + g29) / 3) %>%

mutate(pos\_affect = (g1 + g4 + g6 + g14 + g20) / 5) %>%

mutate(neg\_affect = (g7 + g8 + g9 + g16) / 4)

# Self-Efficacy and NfC Scoring

data = data %>%

mutate (nfc = n1 + n2 - n3 - n4 - n5 + n6 - n7 - n8 - n9 + n10 + n11 - n12 + n13 + n14) %>%

mutate (efficacy = -s1 + s2 + s3 + s4 + s5)

# Normalizing Score Format

data$score\_easy[is.na(data$score\_easy)] <- 0

data$score\_hard[is.na(data$score\_hard)] <- 0

data <- data %>%

mutate (easy = (score\_hard == 0), hard = (score\_easy == 0)) %>%

mutate (score = score\_easy + score\_hard, .keep = "unused")

variables <- data.frame(age = c(data$age), gender = c(data$gender), freq = c(data$gaming\_freq),

exp = c(data$exp), easy = c(data$easy),

score = c(data$score), challenge = c(data$challenge),

tension = c(data$tension), pos\_affect = c(data$pos\_affect),

neg\_affect = c(data$neg\_affect), efficacy = c(data$efficacy),

nfc = c(data$nfc))

variables = variables %>%

mutate (cond = ifelse (variables$easy == TRUE, "easy", "hard")) %>%

mutate (easy = NULL)

remove (to\_rm)

**R Script Used for Computing and Visualizing Descriptive Statistics**

library (psych)

library (tidyverse)

count (variables[variables$cond=="easy",])

count (variables[variables$cond=="hard",])

#Gender Distribution

male = count (variables[variables$gender==1,])/67\*100

female = count (variables[variables$gender==2,])/67\*100

nb = count (variables[variables$gender==3,])/67\*100

not\_mentioned = count (variables[variables$gender==4,])/67\*100

#Score Distribution

ggplot (variables, aes(x = score)) +

geom\_freqpoly() +

xlab("Score") + ylab("Frequency") + ggtitle("Fig. 1.2 - Score Distribution")

# Normalizing Score Distribution

test <- variables

test$score <- log (test$score)

ggplot (test, aes(x = score)) +

geom\_freqpoly() +

xlab("Score") + ylab("Frequency") + ggtitle("Fig. 1.2 - Score Distribution after Logarithmic Normalization")

ggplot (test, aes(x = score, y = cond)) +

geom\_boxplot() +

xlab("Score") + ylab("Difficulty") + ggtitle("Fig. 2 - Score Distribution Across Conditions")

skew (variables$score)

skew (test$score)

ggplot (test, aes(x = score, y = cond, fill = cond)) +

geom\_boxplot() +

xlab("Score") + ylab("Difficulty") + ggtitle("Fig. 2 - Score Distribution Across Conditions") +

theme (legend.position="none")

# Age

mean (variables$age)

sd (variables$age)

# Gaming Frequency Distribution

count (variables[variables$freq == 1,]) / 67 \* 100

count (variables[variables$freq == 2,]) / 67 \* 100

count (variables[variables$freq == 3,]) / 67 \* 100

count (variables[variables$freq == 4,]) / 67 \* 100

count (variables[variables$freq == 5,]) / 67 \* 100

count (variables[variables$freq == 6,]) / 67 \* 100

# Experience with Task

count (variables[variables$exp == 2,]) / 67 \* 100

count (variables[variables$exp == 3,]) / 67 \* 100

# Experimental Group Distribution

count (variables[variables$easy == TRUE,])

count (variables[variables$easy == FALSE,])

**R Script Used for Hypothesis Testing**

library (psych)

library (report)

library (corrplot)

### H1: Perceived Difficulty ~ Perceived Effort

result1 <- t.test (challenge ~ cond, data = test)

report (result1)

sd (test$challenge[test$cond == "easy"])

sd (test$challenge[test$cond == "hard"])

# accounting for frequency

result1\_2 <- aov (challenge ~ cond \* freq, data = test)

report (result1\_2)

result1\_3 <- lm (score ~ challenge, data = test) # statistically significant

report (result1\_3)

## H2: Need for Cognition + Perceived Difficulty ~ Score

ggplot (test, aes(x = nfc)) +

geom\_freqpoly() +

xlab("Need for Cognition") + ylab("") + ggtitle("Fig. 3.1 - Need for Cognition scoring distribution")

skew (test$nfc)

count (test[test$nfc\_cat == "low",])

count (test[test$nfc\_cat == "high",])

ggplot(test, aes(x = nfc\_cat, y = score, fill = cond))+

geom\_boxplot()+

xlab("Need for Cognition")+ylab("Score")+ggtitle("Fig. 3.2 - Score Distribution across Need for Cognition and Perceived Difficulty")+

labs(fill = "Perceived Difficulty")

x <- mean(variables$nfc)

test = test %>%

mutate(nfc\_cat = "temp")

# 2 categories

test$nfc\_cat = ifelse (test$nfc <= x, "low", "high")

result2\_2 <- t.test(score ~ nfc\_cat, data = test)

report (result2\_2)

sd (test$score[test$nfc\_cat == "low"])

sd (test$score[test$nfc\_cat == "high"])

extra1 <- t.test (nfc ~ cond, data = test) # statistically significant

report (extra1)

extra2 <- lm (challenge ~ nfc, data = test)

report (extra2)

sd (test$nfc[test$cond == "easy"])

sd (test$nfc[test$cond == "hard"])

extra1\_2 <- aov (nfc ~ score, data = test)

report (extra1\_2)

ggplot (test, aes(x = nfc, y = cond, fill = cond))+

geom\_boxplot()+

theme (legend.position = "none")+

xlab("Need for Cognition") + ylab("Perceived Difficulty") + ggtitle("Fig. 5 - Need for Cognition Distribution across Experimental Conditions")

# interaction effect

result2\_3 <- aov (score ~ cond \* nfc\_cat, data = test)

report (result2\_3)

### H4: Interest ~ Perceived Difficulty

# Perceived Difficulty ~ Interest components t-tests

result4\_1 <- t.test (pos\_affect ~ cond, data = test)

report(result4\_1)

result4\_11 <- aov (pos\_affect ~ cond \* freq, data = test)

report (result4\_11)

sd (test$pos\_affect[test$cond == "easy"])

sd (test$pos\_affect[test$cond == "hard"])

result4\_2 <- t.test (neg\_affect ~ cond, data = test)

report (result4\_2)

result4\_21 <- aov (neg\_affect ~ cond \* freq, data = test)

report (result4\_21)

sd (test$neg\_affect[test$cond == "easy"])

sd (test$neg\_affect[test$cond == "hard"])

result4\_3 <- t.test (tension ~ cond, data = test)

report (result4\_3)

result4\_31 <- aov (tension ~ cond \* freq, data=test)

report (result4\_31)

sd (test$tension[test$cond == "easy"])

sd (test$tension[test$cond == "hard"])

# Correlation Matrix: Score, Positive Affect, Negative Affect, Tension/Annoyance

matrix <- cor(data.frame(test$score, test$pos\_affect, test$neg\_affect, test$tension))

colnames(matrix) = rownames(matrix) = c("Score", "Positive Affect", "Negative Affect", "Tension/Annoyance")

corrplot(matrix, method = "color", type = "full", addCoef.col = "black",

tl.col = "black", cl.pos = "n")

### Exploratory Hypotheses

# (1) Gaming Frequency and Score

result5\_1 <- aov (score ~ freq\_cat, data = test, )

report (result5\_1)

result5\_2 <- aov (score ~ cond \* freq, data = test,) # statistically significant

report (result5\_2)

# t-test for possible main effects

result2\_41 <- aov (score ~ freq, data = test[test$cond == "easy",])

report (result2\_41)

result2\_42 <- aov (score ~ freq, data = test[test$cond == "hard",]) # statistically significant

report (result2\_42)

result2\_43 <- t.test (score ~ cond, data = test[test$freq == 1,])

report (result2\_43)

result2\_44 <- t.test (score ~ cond, data = test[test$freq == 2,])

report (result2\_44)

result2\_45 <- t.test (score ~ cond, data = test[test$freq == 3,])

report (result2\_45)

result2\_46 <- t.test (score ~ cond, data = test[test$freq == 4,])

report (result2\_46)

result2\_47 <- t.test (score ~ cond, data = test[test$freq == 5,])

report (result2\_47)

result2\_48 <- t.test (score ~ cond, data = test[test$freq == 6,])

report (result2\_48)

ggplot (test, aes(x = as.character(freq), y = score, fill = cond))+

geom\_boxplot() +

xlab("Gaming Frequency") + ylab("Score") +

ggtitle("Fig. 4 - Score Distribution across Experimental Conditions and Gaming Frequency") +

labs(fill = "Perceived Difficulty")

mean (test$score[test$cond == "easy" & test$freq == 1])

mean (test$score[test$cond == "hard" & test$freq == 1])

sd(test$score[test$cond == "easy" & test$freq == 1])

sd(test$score[test$cond == "hard" & test$freq == 1])

mean(test$score[test$cond == "easy" & test$freq == 6])

mean(test$score[test$cond == "hard" & test$freq == 6])

sd(test$score[test$cond == "easy" & test$freq == 6])

sd(test$score[test$cond == "hard" & test$freq == 6])

# (2) Perceived Difficulty and Self-Efficacy ~ Performance

result5\_3 <- aov (score ~ cond \* efficacy, data = test)

report (result5\_3)

result5\_4 <- lm (score ~ efficacy, data = test) # statistically significant

report (result5\_4)

# (3) Score as a predictor of enjoyment?

# Enjoyment predicted by Perceived Difficulty and Performance

result5\_6 <- aov (pos\_affect ~ cond \* score, data = test)

report (result5\_6)

result5\_7 <- aov (neg\_affect ~ cond \* score, data = test)

report (result5\_7)

result5\_8 <- aov (tension ~ cond \* score, data = test)

report (result5\_8)

ggplot (test, aes(x = challenge, y = score)) +

geom\_point() +

stat\_summary (fun = mean, geom = "line", color = "red", aes(group = 1)) +

xlab("Challenge") + ylab("Score") + ggtitle("Fig. 6 - Linear Regression Between Challenge and Performance")

# follow-up tests

result5\_10 <- lm (pos\_affect ~ score, data = test) # statistically significant

report (result5\_10)

result5\_11 <- lm (tension ~ score, data = test) # statistically significant

report (result5\_11)