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The Impact of Strategy Awareness on Student Rationality within the Prisoner's Dilemma Game

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ABSTRACT

This study determined the importance of strategy awareness on student rationality within the Prisoner's Dilemma Game in a Central High School. The Prisoner's Dilemma Game is a model that tests rationality and has an underlying strategy: Rationality can be tested by the number of participants that behave in accordance with the strategy. 57 Participants were provided with three Prisoner's Dilemma Game scenarios via survey to assess how rationally each player would behave in each respective scenario. Participants were randomly assigned to two groups, in which one group possessed the optimal strategy for each scenario while the other group did not. Each scenario had one best option that could have been selected. The two groups were compared to assess if students with access to the optimal strategy behaved in accordance with the strategy more so than the group without the optimal strategy; This is how rationality was measured. The differences in rationality between the two groups were insignificant, thus demonstrating that strategy awareness has a minimal impact on the rationality of students in the scenarios. However, these findings could be further explained by confounding variables, such as Age and AP Classroom Enrollment. The findings signify that students are not rational when making decisions because the students ignored outside information such as the optimal strategy when making a decision within the scenarios. Moving forwards, this demonstrates the need for students to learn how to use surrounding resources to make optimal decisions, which is an important skill outside of high school.

Introduction

Student rationality is arguably one of the most important concepts in education. While many educational institutions emphasize the importance of retaining information in fields such as math or biology, students face difficulty in integrating this knowledge into the real world (Diamond, 2010). In addition, public educational institutions are beginning to stray away from teaching skills that help students make decisions outside the classroom (Abdillah & Tentama, 2019). Consequently, modern high school students have been less capable of obtaining jobs in recent years, likely because students are not being taught how to rationally apply information learned in school to the real world: In 1998, approximately 31% of high school students in the United States were employed as opposed to 19.4% of high school students in 2021. Subsequently, it has become increasingly clear that students are becoming less rational, which may decrease their potential for future success following high school. Accordingly, many educational institutions have begun to advocate for the testing of student rationality, to ensure that students are learning skills applicable to the workforce.

One way of testing for such rationality can be explained through a model: The Prisoner's Dilemma Game. The Prisoner's Dilemma Game tasks players with making a decision to cooperate or defect in a presented scenario. In this model, if players A & B both choose to cooperate, they will both receive one year of jail time each (Moreira, 2016). Similarly, in the hypothetical that player B chooses to defect and player A chooses to cooperate, player A will receive 10 years of jail time whereas player B will receive 0 years, etc. For either player, defecting is the most rational choice. The choice of defecting is known as the best strategy in the game (Schecter, S., & Gintis, H. 2016).

To test if students will utilize the information around them to make a rational decision students will be provided a Prisoner's Dilemma Game scenario. Half of the students will be provided with the best approach to each scenario or in other words, the optimal strategy, and students will be tested if they utilize this information to make the best decision possible in a given scenario. If students are able to make a better decision as a result of learning the most optimal strategy, it shows that students are able to apply information to real world scenarios, demonstrating student rationality. This study aims to assess the importance of strategy awareness in the development of rational decision making among high school students.

		PLAYER B	
		COOPERATE	DEFECT
PLAYER A	COOPERATE	A: 1 year jail B: 1 year jail	A: 10 years jail B: 0 years jail
	DEFECT	A: 0 years jail B: 10 years jail	A: 5 years jail B: 5 years jail

Literature Review

Application of Prisoner's Dilemma Game to Real-World Scenarios

There are a variety of scenarios that could be implemented into a google forms survey to test for student rationality; Specifically, one study analyzed a hypothetical scenario about how two nations competing for resources could be used as a scenario used to test student decision making (Grieco, 1988). The scenario asserts that each player could assume the role of a nation and had the option to cooperate with each other or attempt to defect and collect resources for themselves. Students had the option to either cooperate or defect, and students were viewed as rational if the defect option was selected. The optimal strategy was to defect and selfishly hoard resources. This demonstrated a scenario that could be used to test the rationality of students.

While Joshi et al. (2005) focused on a scenario with an international application, Grieco (1998) asserted that other scenarios could be used to test for student rationality, such as common everyday traffic stops. Joshi et al. (2005) asserted that traffic is caused by selfish behavior that slows the rest of the cars down because some people attempt to reach a destination as fast as possible. Students were considered rational if they decided to drive fast, as opposed to slow. Consequently, rationality was measured based on the percentage of students that choose to drive fast.

Although Joshi et al. (2005) and Grieco (1998) asserted that the Prisoner's Dilemma Game could be used to test student rationality in common everyday scenarios, Mantas et al. (2022) demonstrated why the Prisoner's Dilemma Game can be applied to test rationality. Mantas et al. (2022) put participants through an EEG, which analyzes brain patterns, to determine if the part of the brain responsible for rationality lit up when responding to the Prisoner's Dilemma Game. Mantas et al. (2022) concluded that the Prisoner's Dilemma Game could be used to test if a certain population is rational, because the frontal lobe was activated which is responsible for rationality. In addition, Mantas et al. (2022) provided specific scenarios that can be used to test rationality, which could be implemented into a survey in future research. By providing multiple scenarios with two possible options, a population could be rational depending on how often the group chooses the best option (Mantas et al., 2022).

Rationale behind the Prisoner's Dilemma Game

Simon (1959) delved into the reasons behind why defecting is the most optimal choice; The study asserted that a participant will gain the most satisfaction when choosing the defect option over the cooperation option because it provides the best result for the individual, however, the group does worse off. The most rational option and option strategy would be to defect in the Prisoner's Dilemma Game, simply because it benefits the individual participant the most from their perspective.

Although Simon (1959) focused on individual decision-making and why participants should defect, Orbell & Wilson (1978) focused on group decision-making and the consequences of cooperation. Specifically, Orbell & Wilson (1978) noted that one person in a group playing the Prisoner's Dilemma Game can control the decisions of the other players, and manipulate others to gain an advantage. Ultimately, this demonstrates that players will often perform actions that benefit one individual, at the expense of the group, similar to Simon (1959).

Lewis (1979) asserted that participants are more likely to defect in most outcomes of the Prisoner's Dilemma Game, even if cooperating is mutually beneficial, although Simon (1959) asserts that this may be dependent on the scenario. This demonstrates that people would rather defect because of increased personal benefit, regardless of the benefits gained from cooperation. However, one notable limitation is that Lewis (1979) lacks experimental evidence to support the ideas laid out about decision-making.

Potentially Confounding Variables when Testing for Rationality

Sen (1977) directly addressed the factors that may skew the validity of measuring rationality within studies. Sen (1977) supported that emotions may cause bias when testing for rationality because emotions alter perceptions and beliefs about events. As a result, future studies regarding decision-making would have to account for emotional bias prior to asking people to participate in the study. Sen (1977) additionally advocates for future research to gather experimental data to test the extent to which emotions influence rational decision making.

Gneezy et al. (2011) supports the notion that psychological factors may have an impact on decision-making, similarly to Sen (1977). Gneezy et al. (2011) asserted that if two players play the Prisoner's Dilemma Game across from each other, cooperation ensues instead of the predicted outcome to "defect"; Players feel a moral obligation to cooperate instead of defecting. As a result, players will cooperate with each other instead of prioritizing personal satisfaction, which reduces the probability of participants choosing the defect option. Consequently, this makes students less rational in decision making.

Klopfenstein, K., & Thomas, M. K. (2009) asserts that AP Class Enrollment has a similar effect on the rationality of the players as cooperation mentioned in Gneezy et al. (2011). Students who are enrolled in one AP level class are more exposed to rigorous problems, therefore these students may respond more rationally to a Prisoner's Dilemma Game scenario. Therefore, researchers must consider this factor when evaluating experimental data or results.

Park et al. (2019) investigated that older adults may be more rational than their younger counterparts through a transitive test, which assesses rationality. However, the study found that there was a minimal difference between the rationality of older and younger adults. Notably, one limitation is that Park et al. (2019) did not test if age impacts rationality among adolescents. Further research is needed to assess the impact of age on adolescent rationality.

After considering the underlying factors that may impact the testing of student rationality, it becomes apparent that no studies employ all techniques to minimize bias. While Sen (1977) and Salter (1977) suggest that people may choose to act irrationally because of emotional and psychological external factors, no studies have fully accounted for these biases. In addition, Mantas et al. (2022) demonstrated that the Prisoner's Dilemma Game could be used to test rationality by providing a strategy which impacts how participants respond to a scenario, however, no studies applied this concept to students. By providing students with a strategy and assessing how participants respond to a scenario, the researcher can gain a better understanding of how students use surrounding details to make an informed decision that is applicable to real life. Ultimately, this research attempts to test rationality of adolescent students experimentally, primarily by administering a variety of Prisoner's Dilemma Scenarios through a google forms survey. Information regarding confounding variables (Age and AP Class Enrollment) can also be collected through a survey, whereas other observational methods would fail to do so. This begs the question: To what extent does optimal strategy awareness impact student rationality in the Prisoner's Dilemma Game at Central High School?

This research seeks to answer whether students will be rational throughout Prisoner's Dilemma Game scenarios. Two surveys will be administered to the student participants: One survey does not contain the strategy behind the Prisoner's Dilemma Game (see Appendix A, Figure 6), while the other survey does (see Appendix A, Figure 7). Through statistical analysis, the researcher will determine whether student rationality changes due to strategy awareness, followed by an interpretation and discussion of the results and their implications.

Methods

Study Design

This analytical study employed an experimental design through the use of surveys to assess the impact of optimal strategy awareness on student rationality within the Prisoner's Dilemma Game. While an observational study seems applicable to this research at first, these designs cannot avoid biases. For example, Salter (2014) suggests that participants in the Prisoner's Dilemma game playing face-to-face would be compelled to cooperate with their opponent rather than to defect. To avoid this bias, the method employed by the researcher is modeled more closely to Joshi et al. (2005), in which participants were assigned to groups and surveyed to determine how each person would respond in a Prisoner's Dilemma scenario with the control of confounding variables.

Two surveys were constructed that contain information about the instructions of the Prisoner's Dilemma Game along with questions that control the effects of confounding variables on student rationality, such as age and AP class enrollment. Both surveys display questions regarding age and whether or not students have been enrolled in at least one AP level class, followed by a description of three scenarios that can be used to test for rationality. The three scenarios were based on the outline promoted by Mantas et al. (2022): The first scenario prompted students to either advertise or not advertise for a hypothetical sales pitch, the second hypothetical scenario prompted students to either choose the "left" path or "right" path to gain the most candy possible, and the third scenario prompted students to either choose the "A" grade or "D" grade paper in a competitive classroom scenario (See Appendix A, Figure 6). Students can make a decision between two options within each scenario, and one of the options is considered the most optimal. Although the two constructed surveys are nearly identical, only one form contains the strategy of the Prisoner's Dilemma Game. This modified survey will be distributed to the treatment group (See Appendix A, Figure 7). In contrast, the form without the strategy will be distributed to the control group, and students will be randomly assigned to each group (See Appendix A, Figure 6). The strategy embedded in the form of the treatment group states the most rational choice in each scenario (See Appendix A, Figure 7). Through statistical analysis, the two groups will be compared to determine whether strategy awareness impacts student rationality. The research is comparative in nature because of the comparisons between the treatment and control groups. In addition, the experimental research can determine the causal relationship between rationality and optimal strategy awareness.

The hypothesis asserts that student rationality will be affected by Prisoner's Dilemma strategy. The alternative hypothesis, which is assumed to be false unless evidence supports it, asserts that rationality is affected by Prisoner's Dilemma strategy.

Participants

This study collected data at a Central High School (CHS) during Student Resource Time (SRT), a period in which students can work on homework assignments and ask teachers questions. Excluding participants outside the age range of thirteen to nineteen was necessary; Mantas et al. (2022) stated that rationality may be higher in older populations, and younger populations may not be cognitively capable of rational decision-making. Students were randomly assigned to be in the experimental group and were given the google form containing the strategy whereas other students were assigned the control group in which students were given the google form without the strategy. Consequently, the two google forms surveys were distributed to freshmen, sophomores, juniors, and seniors in various SRT rooms through a non-probabilistic sample. Although the assignment to each group was random, convenience sampling was necessary to increase the number of responses to the survey.

Voluntary response bias could not be avoided because participation was optional. Students who did not participate in the study were often working on assignments or had left the room. As a way to increase the response rate, students were compensated with a piece of candy.

Ethics

All survey materials (see Appendix A and B) were approved by the Central High School's Ethical Research Committee before the distribution of these items. Guardians and participants were also required to sign a written consent form prior to a student's participation in the study because all participants were 18 years old or younger. Teachers consented to the distribution of surveys to the classrooms, and participants were informed that participation in the research was voluntary and that they could leave at any time. Although personally identifying information was collected in the surveys, the information was used aggregately and was not tied to any student in particular which maintained the anonymity of the participants. To ensure the anonymity of the researcher, the researcher used a dummy email account instead of a personally-identifying email. Therefore, participants and the researcher alike were kept anonymous and ethical concerns were mitigated.

Procedure

Two surveys were created to assess the impact of optimal strategy awareness on student rationality within the Prisoner's Dilemma Game. The independent variable, optimal strategy awareness, is conceptually defined as the students' acknowledgment of the best approach in the game. The dependent variable, rationality, can be statistically measured by the percentage of decisions that do not involve cooperation, because defecting is the most optimal strategy in a Prisoner's Dilemma Game scenario. Lewis (1979) suggested that the rates at which students choose the defect option can accurately measure rationality, which explains the researcher's reasoning to collect this information. The defect rates can be operationally defined by the percentage of students who defect in each group in the experiment. Within each survey, students were tasked with making a decision in scenarios modeled after the Prisoner's Dilemma Game. For example, students assumed the role of a competing business that had to make a decision between cooperating or defecting with another business. Students were asked to advertise (cooperate), or not advertise (defect). Each respective outcome was listed in the description of the question.

On administration dates, the researcher entered the Student Resource Time classroom and asked for teacher permission to distribute the survey. Following this, students who opted to participate were randomly distributed the first google forms survey and the other half of the students were distributed the second google forms survey. Instructions were provided by the researcher, and the researcher mentioned that the completion of the survey would take approximately five minutes to complete. Students who participated were compensated with a piece of candy. The researcher visited twelve SRT Rooms and gathered thirty participants from the treatment group, and twenty-seven participants from the control group. The process implemented by the researcher was the best possible way to mitigate potential sources of bias. According to Sen (1977) and Salter (2014), psychological emotions led to an increase in cooperation in the Prisoner's Dilemma game. Hence, the researcher distributed the two surveys in a similar process used by Joshi et al. (2005), which mitigated cooperation bias and instead established validity.

Following the distribution of the surveys to every classroom, data was pooled into a google spreadsheet for further statistical analysis (See Appendix B). The data was also separated by which survey was administered. As a result, the differences in the rates at which students choose the defect option in each treatment group can be easily identified by comparing the data between the groups, to determine how optimal strategy awareness impacted student rationality.

Results

Students who were exposed to the optimal strategy of each scenario did not have the predicted difference in rationality between groups 1 and 2 as stated in the hypothesis. The difference in rational decision-making between students in groups 1 and 2 in the first scenario was minimal: Group 1 had 89% of students advertise, whereas group 2 had a slightly less 83.3% of students advertise. The most rational option was to choose to "Advertise", suggesting high rationality within both groups in the scenario. However, the difference between the two groups could have been attributed to randomness alone associated with sampling (See Figure 1).

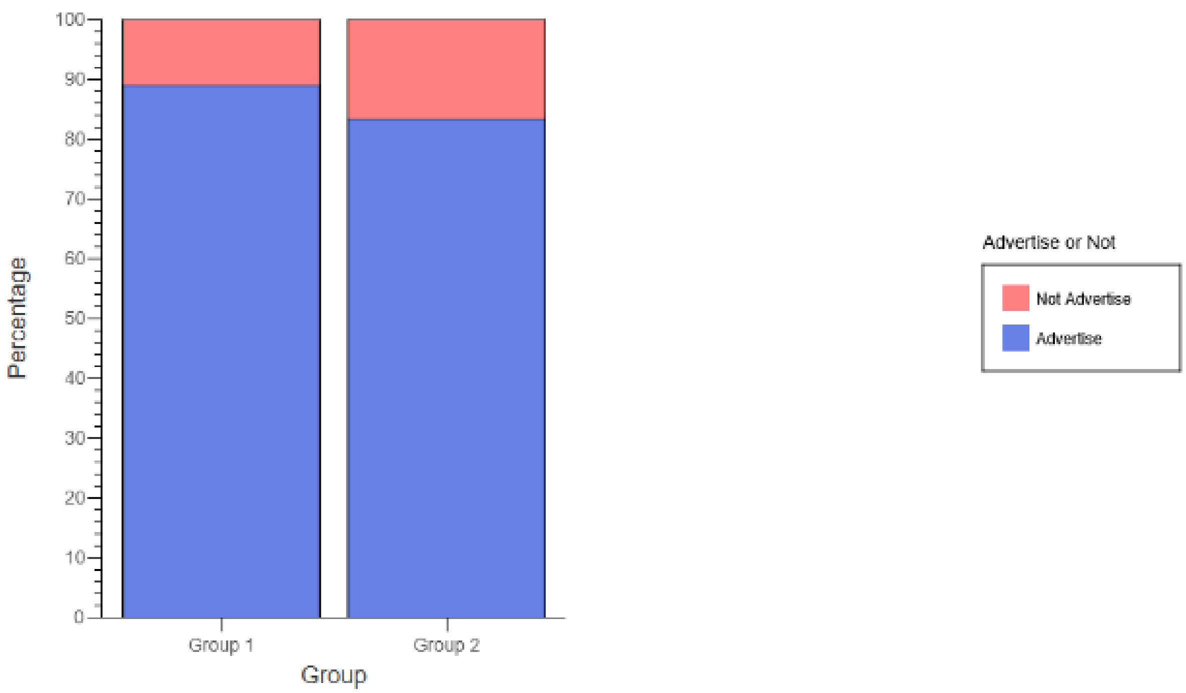

Figure 1. Relationship between Rationality and Group in Scenario #1

Choosing "Right" and "Left" in the second scenario are both equally rational options, suggesting that the expected rate of students who choose "Right" should fall around 50%. Unlike Scenario #1, the situation presented in Scenario #2 created a difference in decision-making between both groups. Group 1 had 48.1% of the students choose the "Right" path in the second scenario and Group 2 had a smaller 33.3% of the students choose the "Right" path in the second scenario. The difference in the rate of the "Right" path being chosen was approximately 15%. Noticeably, Group 2 deviated from the expectation of Mantas et al. (2022), while Group 1 fell around the expected value (See Figure 2).

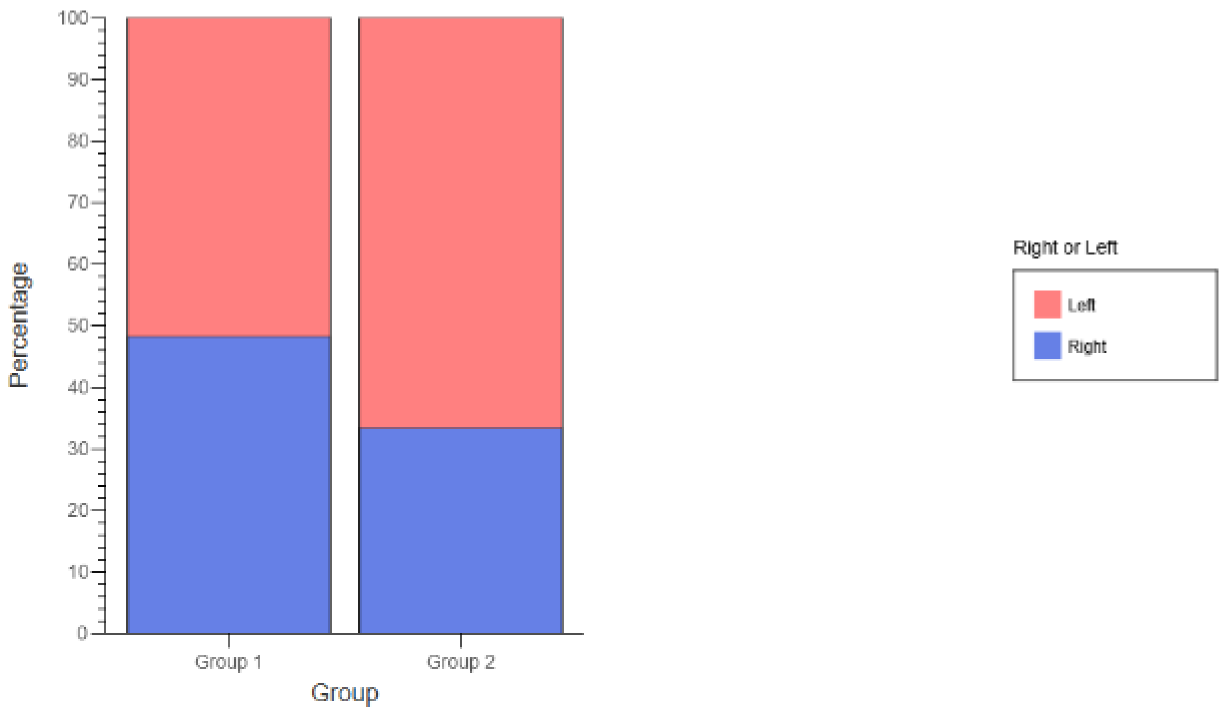

Figure 2. Relationship between Rationality and Group in Scenario #2

In Scenario #3, the most rational option was to accept the paper with an "A" grade. The optimal strategy presented in the third scenario had a minimal impact on the rationality of students between the two groups. The rate of students in the first group who chose to accept the paper with an "A" grade was 92.6%. Group 2 had a slightly larger rate of students who chose to accept the paper with an "A" grade of 93.3%. The data suggests that students were highly rational in decision-making because almost every participant chose the best option in this scenario, regardless of group (See Figure 3).

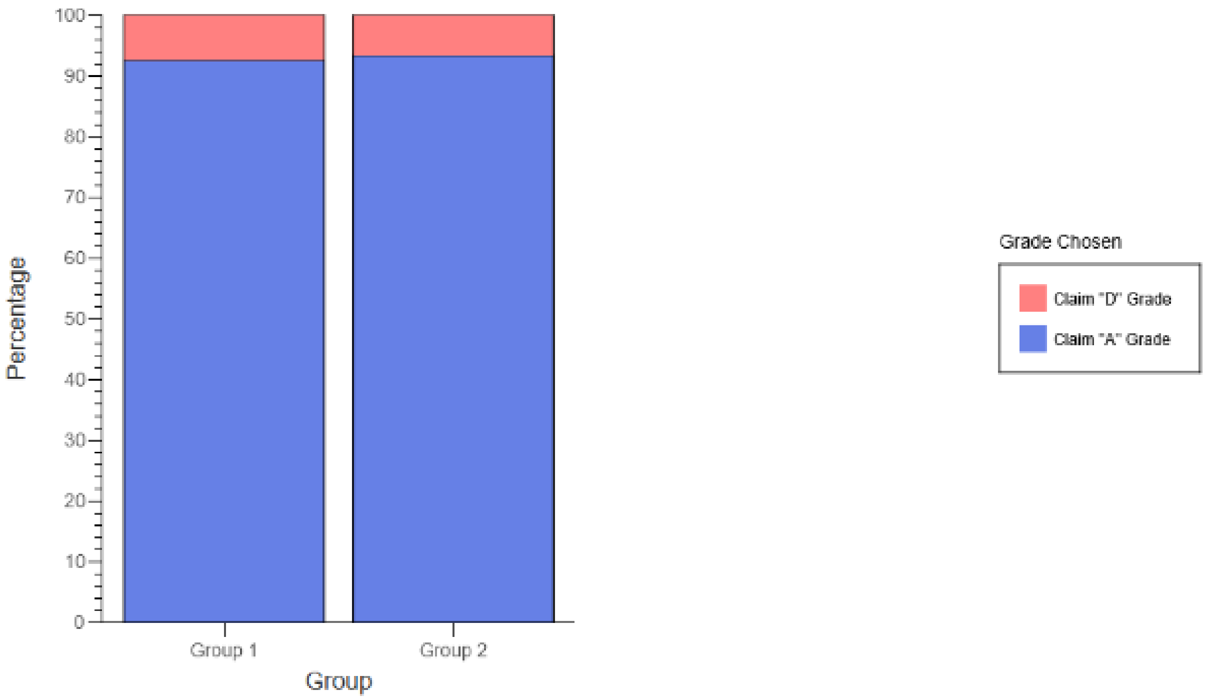

Figure 3. Relationship between Rationality and Group in Scenario #3

After analyzing the rates of rationality in each scenario, a statistical test was employed to determine if there was a significant difference between the rates of rationality across all scenarios. The distribution of rationality across all three scenarios is similar for the control and treatment groups, suggesting that there is no statistically significant evidence to suggest a difference in rationality (Chi-Squared Test for Homogeneity, 2 d.f., $p = .7506$, $\alpha < .05$).

The average age between each group, a potentially confounding variable, was computed. The mean age for group 1 was 16.4 years, which was larger than the mean age for group 2 of 16.2 years. Conversely, the standard deviation for group 1 was .747 years (One Variable Statistics, $n = 27$), which was smaller than the standard deviation for group 2 of .887 years (One Variable Statistics, $n = 30$). The standard deviation indicates how far the average participant within the group may fall from the average age. The medians of both groups were identical, indicating that the middle value of age in the dataset was 16.5 years old. The red cross in Figure 4 indicates the mean value (See Figure 4).

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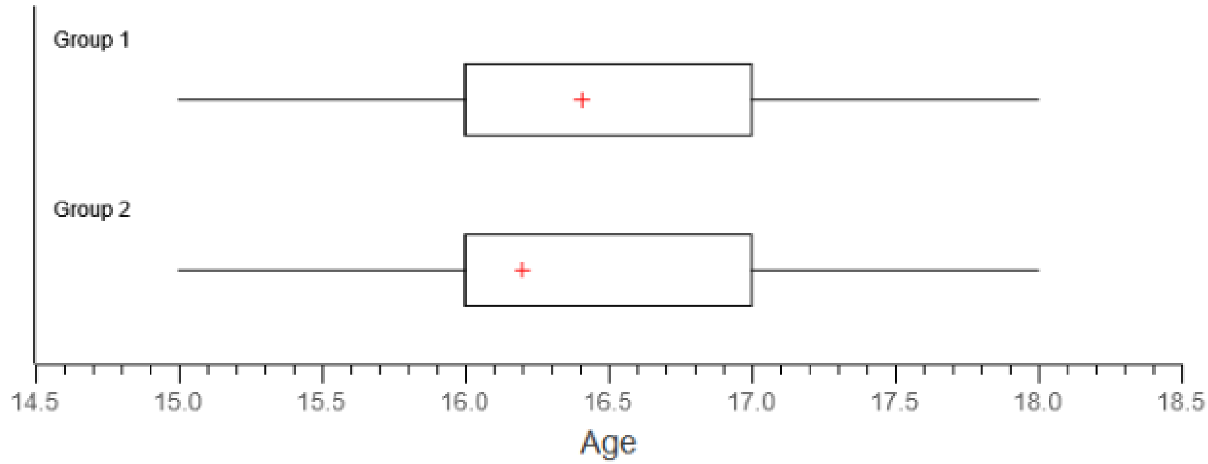

Figure 4. Relationship Between Age and Group

Another confounding variable that may have influenced the distribution of rationality across the three scenarios would be AP Class Enrollment. All 27 participants in group 1 have been enrolled in at least one AP class, while 27 of the 30 participants in group 2 have been enrolled in at least one AP class. The AP Class Enrollment proportion in group 1 is 10% bigger than the proportion in group 2, which is large. The increased AP Class Enrollment in group 1 may have increased levels of rationality throughout the scenarios (See Figure 5).

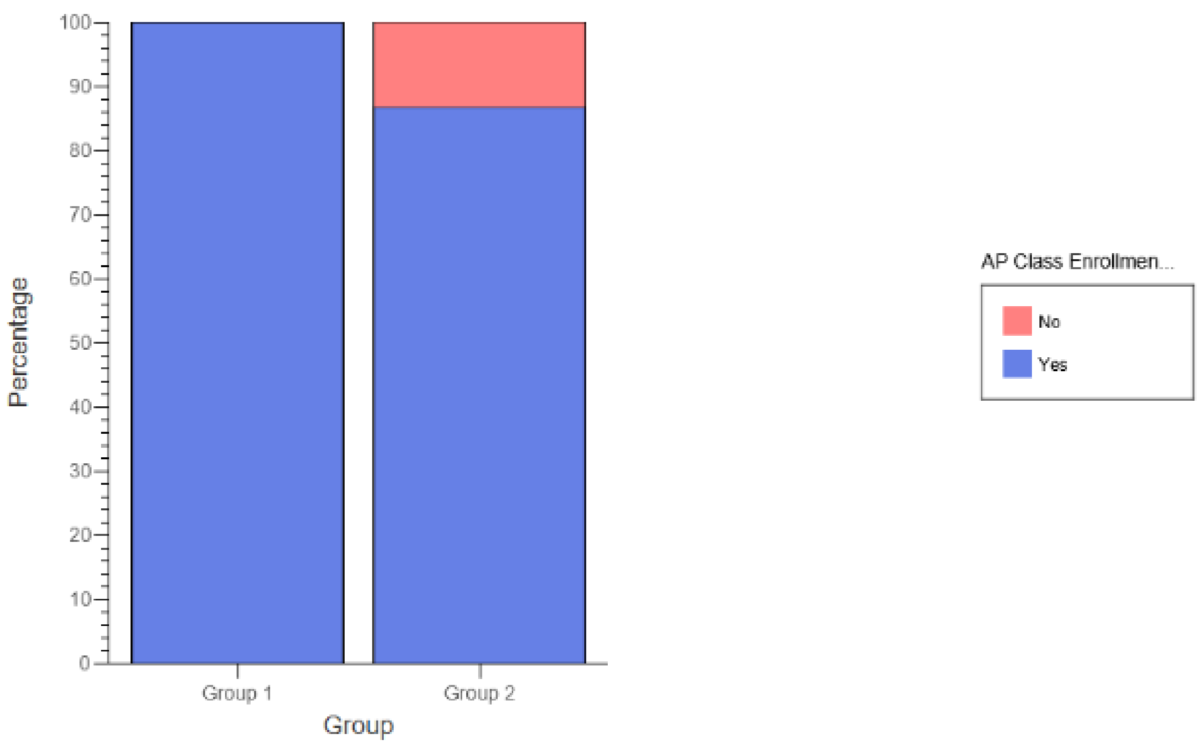

Figure 5. Relationship Between AP Class Enrollment and Group

Discussion

The purpose of this research study was to determine the impact of optimal strategy awareness on student rationality in the Prisoner's Dilemma Game through the use of a survey. Although many studies emphasize the real-life applications of the Prisoner's Dilemma Game (Grieco, 1998 & Simon, 1959), previous studies have ignored applying the game to students. In addition, further studies have suggested that external factors such as emotions may have caused irrational thinking during decision-making processes (Sen, 1977). Consequently, the method used to test rationality was administered through two google surveys to reduce preliminary factors that may induce irrationality. It was hypothesized that optimal strategy awareness would increase student rationality, however, the differences in student rationality between the control and treatment groups were insignificant. Thus, the hypothesis could not be supported by data evidence to suggest that optimal strategy awareness causes increased student rationality. However, Mantas et al. (2022) asserted that optimal strategy awareness should cause an increase in student rationality, which contradicts the findings of this researcher's study.

This study modeled the scenarios after the suggestion outlined by Mantas et al. (2022) in order to test student rationality. The findings in Scenario #1 asserted that students chose the most rational option around 87% of the time, and failed to find a significant difference between the treatment and control group. However, Mantas et al. (2022) suggests that 100% of adult participants should choose the most rational option given the information in the scenario.

What may cause this unexplained outcome presented within the study? Aside from attributing differences in rationality to the age gap between both groups, AP classroom enrollment may be a factor. Students who are enrolled in AP classes are more exposed to rigorous and difficult questions that require high levels of logic to answer (Klopfenstein, K., & Thomas, M. K. 2009). Consequently, these students may possess higher levels of rational decision-making. In the study, although students in Group 1 did not have access to the optimal strategy in the scenarios, all 31 participants had been enrolled in at least one AP-level course and despite Group 2 having access to the optimal strategy of every scenario, only 90% of the students had been enrolled in at least one AP class. Consequently, it was hard to assess the extent to which AP Class enrollment or optimal strategy awareness impacted rationality, which could have explained why there was no increase in student rationality when comparing the two groups because the two factors could have offset each other.

Another factor that may explain the insignificant results for Scenario #1 could be attributed to age. The data collected from both groups suggest that students from Group 1 were slightly older, 0.25 years on average than students in Group 2. Although this difference in age was minimal, it suggests that Group 1 may have been more rational decision-makers due to students being more cognitively developed (Mantas et al. 2022). Despite not having the optimal strategy, students in Group 1 may have been as rational as students in Group 2 who did have the strategy, due to the difference in age between the groups. While age could explain the minimal difference in student rationality between groups, it could also explain why students did not choose the most rational option 100% of the time as outlined by Mantas et al. (2022). The sample used in Mantas et al. (2022) was composed of only adults, implying that participants were older and may have tended to choose the most rational option more often than the student sample used in this research. Thus, age may explain the contradictory findings.

The findings in Scenario #2 partially aligned with the findings of Mantas et al. (2022). The two possible options that students could have selected from in the scenario were equally as rational, suggesting that either option should be chosen around 50% of the time. While Group 1 matched this expectation, Group 2 slightly deviated from this expectation. This deviation was likely due to AP class enrollment and age as explained above.

The findings in Scenario #3 aligned with the findings of Mantas et al. (2022). Mantas et al. (2022) suggested that similarly to Scenario #1, students were expected to choose the most rational option 100% of the time. The students in both groups closely followed the expectation and chose the most rational option around 93% of the time. Although there were minimal differences in the rationality between the groups with and without the strategy, students chose the best option the majority of the time. As a result, there was little room for improvement by gaining access to the optimal strategy, which likely caused insignificant findings between groups 1 and 2.

This study suggests that age and AP class enrollment may be the primary factors in the insignificant impact of optimal strategy awareness on student rationality, however, there are some limitations to address that may have contributed toward these contradictory findings to Mantas et al. (2022). The sample size used in the study was quite limited, with only 57 participants in both groups combined. Consequently, an increased sample size could have contributed to more accurate findings because the sample would be more representative of the student population. Furthermore, these findings may only generalize to students from a central suburban high school that contains grades 9-12 and nearly 6000 students, because the sample was drawn from this population. Consequently, the findings may not be easily applied to other high schools due to the uniqueness of the school the students were drawn from. Lastly, only students present in the Student Resource Time class may have participated in the study. This may have excluded students that were not enrolled in the class, such as seniors taking the Transition to College Program who may have chosen to leave the class, or special education students who were not present during the time. In addition, many students that chose to not participate in the study were often occupied with classwork and opted out. Accordingly, the findings may not be applicable to students under the same conditions.

Conclusion

To summarize, the findings suggest that providing students with accessible information that may influence their rationality fails to cause a difference in decision-making processes. Although the optimal strategy did cause a difference in the decision-making of students in certain scenarios, the difference was insignificant overall across all scenarios. It could be postulated that students need to be taught how to use the information around them to make optimal decisions as an adult would, to increase rationality. Although all students in the study understood the scenarios that were suggested, it is also imperative that students understand the resources available in making decisions. Without understanding the full context of a problem presented to a student, irrational decision-making may occur and cause students to struggle in and outside the school. This effect could be seen due to the optimal strategy having no effect on student rationality. The school system should also encourage more students to take AP level classes due to the amount of hardship and logical thinking skills that students will develop as a result of the course (Klopfenstein, K., & Thomas, M. K. 2009). Consequently, these classes would enable students to increase their level of rationality following high school graduation. Before students attempt to engage in rational thinking, students should also try to limit the influence of emotions that may arise in a particular situation, which was limited in this study. Certain emotions such as anger or frustration would cause a student to irrationally make decisions that are often regretted, which causes illogical thinking (Sen, 1977). By managing emotions, students will develop self-regulation skills that may be useful in not only rational decision-making but also during interactions with peers.

Looking forward, researchers should further explore how students can become more rational, and whether this responsibility falls on the school system. Throughout earlier levels of education, teachers could teach students basic levels of decision-making in applicable scenarios, and guide students through the consequences of each decision. However, parents may feel uncomfortable with teachers teaching decision-making because political viewpoints could easily get involved. Either way, more research is necessary to determine the potential factors that will contribute to successful decision-making among students.

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