Perception Meets Examination: Studying Deceptive Behaviors in VR

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Abstract

Students cheating on an exam in an academic setting creates an environment where one person (the student) must reason about the perception of another (the teacher). In exploring the student's mindset, trends concerning how humans make decisions based on their understanding of another human's intentions and knowledge can be uncovered. In this work, we study human cheating behavior through simulated examinations in virtual reality, showing that the teacher's animacy and orientation plays a large part in the student's reasoning of the teacher's awareness. By utilizing a virtual classroom setting and accurately tracking a users behavior (through head tracking, eye movement, etc.), we have also demonstrated how a novel virtual reality approach can be used for such experiments involving human behavioral observations, which can be further explored in other cognitive science research experiments.

Keywords: deceptive behavior; behavior modeling; virtual reality; game experimentation; human vision; Theory of Mind

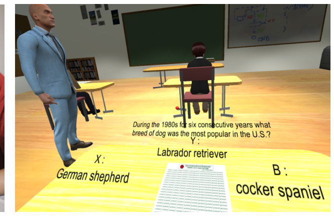
Introduction

Imagine you are a teacher surveying your classroom of students who are taking a final exam. You know that the exam is very difficult and you expect that some students may attempt to cheat. Perhaps you find yourself scanning the room for signs of cheating behavior. But, what do such signs look like? A student looking around the room could simply be in the process of managing their thoughts. If a student is looking straight at you for a while, are they waiting for you to look away or are they wondering if they should ask you a question? How can you determine which students are simply feigning innocence while planning a cheating attempt? What if you have a large classroom of students; how would you be able to keep an eye on all of them at once?

Cheating remains a common problem in examinations, which creates an interesting scenario for cognitive psychology research in its need to have one person relying upon their perceptions of the intentions of another person to behave. In a classroom, the student must rely upon the teacher's actions and movements in order to determine when the best window to cheat off of another student's exam is. How the student reasons about a teacher's intentions, formulates the right time to cheat, and performs certain behaviors to "trick" the teacher are areas that have yet to be explored in a way that does not simply rely on asking students how they cheat. Discovering how a cheater successfully accomplishes his or her task is related to the cognitive science concept of the *Theory of Mind*, defined as "a mechanism that helps [one] to make sense of the behaviour of others in specific contexts and to predict their next action" (Dias, Aylett, Paiva, & Reis, 2013). In the situation of cheating during an examination, the student must predict what the teacher is perceiving in order to gauge the success of their cheating attempt.

In this work, we study the signs and visual behaviors of cheating through virtual reality. Having actual students in real life to participate in our experiments and produce the cheating data gives us a realistic dataset to visualize and analyze how university students may actually cheat on classroom examinations. We recreate the cheating situations captured in

(a) Cheating in a real classroom



(b) Our game

Figure 1: (a) Cheating in a real classroom during an exam. (b) A screenshot of our game that mimics the settings of a real exam. The player cheats during a simulated examination in virtual reality while avoiding getting caught by the teacher similar to a real-life situation.

virtual reality to establish ecological validity and track various factors of the participants' behavior with respect to the state of the teacher.

Figure 1(b) shows a screenshot of our game. Our game premise is inspired by Sunken Places' virtual reality game "Classroom Aquatic". In their game, the player is asked to complete their multiple-choice examination within a time limit by cheating off of other students' examinations, avoiding the teacher's and students' gazes, and using objects as distractions to answer the questions correctly. This premise takes an ordinary situation and recreates it in virtual reality, encouraging players to use deceptive behavior to complete a task. From a cognitive science standpoint, such a game setting is interesting as it provides a good scenario for studying how humans exhibit cheating behavior and for understanding how humans judge the actions of others to be deceptive.

The major contributions of our work include the following:

- Analyzing how students cheat on classroom exams based on their behavior within a virtual setting.
- Demonstrating that virtual reality environments can produce a way to objectively gather data on human behavior.

Hypothesis

Through our experiments, we seek to answer the question of how students use information of a teacher's movements to perceive the teacher's intent (i.e. how does the teacher's movement and placement in the room affect the student's judgment on when it is "safe" to cheat?). This question contributes to the discussion of the Theory of Mind and how humans process information of others' behaviors to make judgments. Inspired by the previous research on animacy and how that influences a human's decision-making process, we hypothesize that (1) players will cheat most often when the teacher is completely turned away from them. For this hypothesis, we believe that players will assume that the teacher will keep walking in the same direction, away from them, for a long enough time for them to safely cheat. As for how the players will choose to cheat, we also make the hypothesis that (2) the players will not look directly at another students' exam, and will instead cheat while employing their peripheral vision in order to appear innocent to the teacher and also to keep an eye on the teacher as much as they can.

Related Work

Common Cheating Behavior in Exams. Prior methods used to prevent cheating and to catch potential cheaters are common in research literature on the topic of student cheating. The factors behind why students cheat is well-documented and analyzes how certain variables affect the students' likeliness to cheat including gender, GPA, parental pressure, etc. (Batool, Abbas, & Naeemi, 2011). Although such findings are useful, their applications in preventing cheating are difficult to place given that one may not be able to generalize which students are likely to cheat based on their personal life (such as parental pressure) as well as the fact that some of these variables may not be accessible by an educational institution. An examination of classrooms and learning environments that are best able to dissuade cheating has been performed in prior research (Cizek, 2003), which found that students tend to cheat less often when (a) classes are smaller; (b) classroom conditions (both physical and instructional) are established that are conducive to learning; (c) instruction, assignments, and examinations are clear, well-designed, meaningful, and relevant; (d) teachers take reasonable steps to prevent cheating . While (a) is an issue that is generally assumed to be handled by the educational institution, and (b) and (c) are obvious goals that any class setting should aim to achieve, it is (d) that we are most interested in cultivating by finding out how students actually cheat.

Many of the methods used to discover how cheating is conducted is qualitative and frequently relies upon students' readily answering questions on the matter (e.g., (Batool et al., 2011; Shon, 2006; Yee & MacKown, 2009)). Relying upon student responses alone is problematic for the obvious reason that students could easily lie and fail to realize their exact behavioral habits when trying to be deceptive. By taking data from "cheaters" in a quantitative way through automatically tracking their actions throughout a cheating session, this problem would be resolved. Previous attempts to automate detection have applied text-mining based approaches, which only evaluate cheating after the fact and is limited to open-ended exams (Cavalcanti, Pires, Cavalcanti, Pires, et al., 2012). We are more interested in studying the cheating behavior at the instant it occurs, which forces the student to rely upon his or her reasoning of the teacher's perception, as it is highly relevant to the Theory of Mind.

Prior Cognitive Science Studies on Deceptive Behavior. According to previous studies, students cheat by first "qualifying the professor": determining how likely they could get away with cheating based on evaluating the teacher's behavior (Batool et al., 2011). This is an area that we would like to explore further as it is an extension of a human's Theory of Mind, defined as the ability to infer the full range of epistemic mental states of others, i.e., beliefs, desires, intentions and knowledge (Dias et al., 2013). This is a mechanism that helps to make sense of the behavior of others in specific contexts and to predict their next action. Through our experiments and analysis, we investigate the Theory of Mind in that we are trying to find out how people figure out whether or not the teacher is catching on to them and, based on the teacher's behavior, when it is safe to cheat.

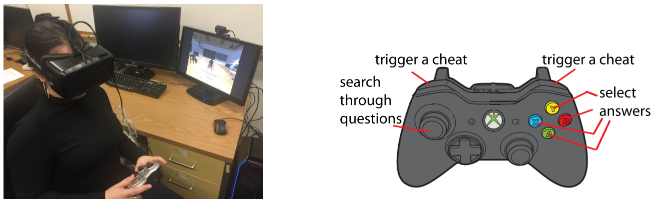
In a recent study, (Dias et al., 2013) established a game in which different artificial intelligence models with varying levels of Theory of Mind were set to perform deceptive behaviors in a game setting, finding that those with higher levels of Theory of Mind (and thus a greater ability to reason and make inferences on others' behaviors) were more successful in deceiving, showing how frequently deception is founded when making judgments upon the actions of others. In our experiments, we examine the behaviors of the human players against the actions of a virtual teacher to discover how humans may similarly reason about the teacher's behavior in order to be successfully deceitful.

Gao's et al. (Gao, Newman, & Scholl, 2009) research concerning how animacy is involved in a person's reasoning on intent provides a possible explanation for what we are observing in our players' behavior. Their study found that humans rely on the direction and orientation of an object to perceive its animacy, movement, and intent. Subjects were more likely to reason that a wolf shape was "chasing" a sheep shape if orientation was present. Therefore, animacy and orientation of movement may be influential when humans apply the Theory of Mind. In our experiment, we will observe to what extent the player will use the teacher's animacy and movements in making their decision of what time is best to cheat.

Investigating how humans reason about their game opponents in game settings is well-documented and is helpful to those in game-development who are concerned with realistic AI mechanisms. Prior research in turn-taking games follows a similar setup in exploring the Theory of Mind and looks into "which rules govern human strategic thinking" (Halder, Sharma, Ghosh, & Verbrugge, 2015). Such findings inspired us to determine which aspects of human behavior we should track and record, taking note to include timing and duration of actions (such as cheating) in our own experiments. However, unlike such studies, we are dealing with continuous gameplay and so we cannot delineate a player's choices in a clear-cut manner as we would in a turn-taking game. Having a continuous gameplay setup serves our purpose in mirroring a situation that would take place in everyday life.

Using Games for Cognitive Science Research. The involvement of videogames into academic research has an established, albeit relatively new, presence in academic research. Previous branches of research involving videogames in the fields of Cognitive and Social Psychology have studied the effect of entertaining games on basic cognitive skills while another has researched the success of educational gaming (Killingsworth & Clark, 2013). Instead of contributing to either of these branches, our experiment seeks to instead use a videogame format in order to observe human behavior, which is an ability afforded to us through the use of virtual environments that are now even more immersive with the aid of a suitable virtual reality headset.

Previous research studies have used virtual reality technology to recreate real-life situations and examine human behavior in such instances (Kozlov & Johansen, 2010; Olivier, Bruneau, Cirio, & Pettré, 2014; Li, Liang, Quigley, Zhao, & Yu, 2017; Rovira, Swapp, Spanlang, & Slater, 2009). These studies have found that virtual scenarios are a good fit in measuring human responses to real events due to the close correspondence in human behavior between the two environments



(a) Oculus Rift VR headset (b) Player controller

Figure 2: Experiment setup. The participants performed the examinations using (a) an Oculus Rift virtual reality headset and (b) a Microsoft Xbox 360 game controller.

as well as the fact that the virtual reality settings can be fine-tuned by the researchers (Rovira et al., 2009). If the virtual setting is close enough to pass as its material counterpart, it is safe to claim that observations made on participants are valid.

Approach

Overview. To study how students cheat, we seek to gather information on how players cheat on exams within a game session that models the real-life situation. In our experiments, the player takes on the role of a student taking a multiple-choice paper exam. The player is immersed in a virtual classroom environment and is asked to achieve two objectives: (1) answer as many questions on the examination correctly as possible by cheating off of other students' exams and (2) avoid detection of the teacher. If the teacher is able to catch the student in the act of cheating, the player will fail the task and that round will end.

User Interaction. Figure 2 depicts the experiment setup for the game sessions. We decided to use an Oculus Rift DK2 as our virtual reality hardware setup due to its ability to conduct the sessions in a small space and immerse players within the game setting. A Microsoft Xbox 360 wireless controller is used as the primary controller for which the player cheats and answers questions with. The player can change his viewpoint and shift his gaze as he would in reality with the use of the virtual reality headset. Other primary modes of interaction will be the act of cheating, which is triggered when the Left/Right Bumper Button is held down by the player (the answer retrieved from the examination paper of the classmate sitting on the left or right will be displayed); and the abilities to switch through and answer examination questions, which are respectively achieved by pressing Left/Right on the directional pad and either A/B/Y/X.

Virtual Environment Design. We designed a 3D virtual environment in the form of a classroom in which the player is a student surrounded by other students at individual desks, much like how most classrooms are set up at colleges today. The classroom objects, the teacher, the player character, and the other 3D student models were found at the Unity Asset Store. The design of the classroom is not flashy nor distracting so that players can focus on the task at hand.

Gameplay. The exams of the students to the left and right sides of the player will contain a correct answer to one of the questions on the exams; these answers will change in a preset interval every 5 seconds so that all answers can be obtained by cheating. The teacher moves along a preset path to hit certain points along the classroom, rotates about every six seconds, and seems to be checking over the room for signs of potential cheating. The path of the teacher is shown in

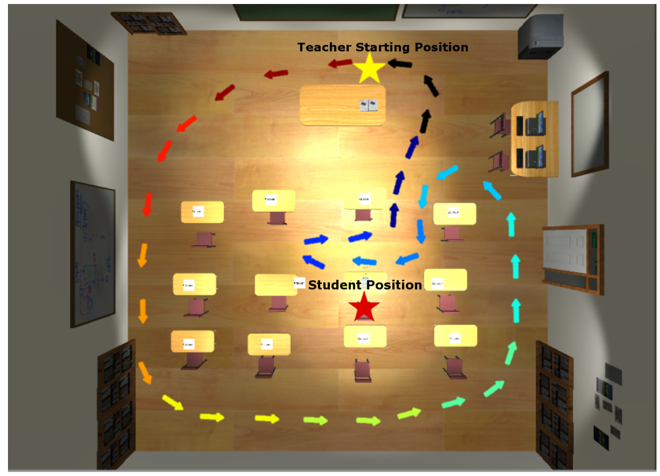


Figure 3: The path of the teacher during the game. Walking through the path once takes about 80 seconds and the teacher cycles through the path until the player finishes his exam in the round, which usually takes about 100-200 seconds. Arrow directions correspond to the orientations of the teacher.

Figure 3. The questions that show up on the player's exams are derived from the website "Trivia Country" (Trivia Country, 2016). We chose questions from this website due to their specificity and very low chance that participants would know the correct answers. For example, one question we ask participants on the exam is: *The Philadelphia mint started putting a 'P' mint mark on quarters in which year? Answer Choices: a)1980; b)1960; c)1950; d)never*. We give the participants an incentive to cheat by telling them that the number of correct responses they answer is important to getting the maximum amount of money. Since the multiple-choice questions are derived from random, factual knowledge that the participants will most likely not know the answer to, cheating becomes a necessity to gathering the correct answers. Furthermore, we give an incentive for the players to cheat wisely by telling them that, if they are caught cheating, their potential to gather the maximum amount of points per round will be cut short. The player is also told that the teacher is powered by an advanced artificial intelligence and a human vision model so that he can perceive the environment like a real human, so that the player treats the teacher's actions with severity. In actuality, the teacher has a limited, cone-shaped range of vision that functions as a spotlight to detect cheating if the player is within the cone of vision and holding down the cheat button at the same time.

Data Collection. In order to gather data through the game session playthroughs, we constantly track the position and orientation of the teacher model. The position and orientations of the the teacher's head and the player's head movements are recorded during gameplay for later analysis. We measure the user's visual attention through game scripts that track an approximation of the player's gaze by creating a ray at a point where the player is looking, as well as taking note of at what time the player is cheating and which paper the player is cheating off of (either the left or right exam). During the player sessions, we also record a video of the gameplay, from both the teacher's and the student's point of view. Refer to our supplementary video which showcases some of this footage.

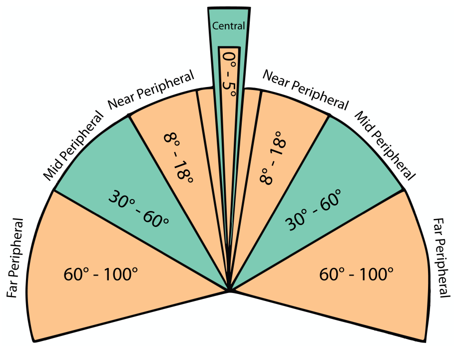


Figure 4: Human's field of vision.

Experiments

Subjects. 25 participants were recruited to conduct this study with 22 being college students and the rest in high school and middle school. The subjects were recruited through emails sent out to the Computer Science department at UMass Boston as well as through word of mouth. About 60% of the subjects were of a Computer Science background. None of the students had played the aforementioned Classroom Aquatic game. Of all the subjects, there were 14 males and 11 females. Each player session consisted of 3 rounds. The participants participated individually for approximately 10 minutes for each player session and so completed each round in about 3 minutes. Participants were paid $10 for their time upon completion of their experiments.

Implementation. The virtual reality program was run on a desktop computer installed with an AMD FX 8350 Eight-Core Processor (4.00GHz), 16GB memory (RAM) and a MSI Radeon R9 390 8GB Graphics Card. Participants were given a Xbox 360 wireless controller and an Oculus Rift DK2 headset to play the game created using the Unity game engine.

Briefing. Participants were given instructions on how the controls of the game functioned through a short tutorial session. This tutorial session allowed players to understand how to answer exam questions, how to cheat, as well as to become accustomed to the game surroundings. The virtual teacher was not introduced in the tutorial session. The players were then told the following message before the start of the game session:

You are a student looking to get a decent grade on an in-class, multiple-choice exam. The answers to the questions correspond to the A-B-Y-X buttons on your controller. To gain a good score, you can cheat off of the exams of the students to the left and right of you. Hold down the left or right bumper to cheat off of their exams, which will have a correct answer to a question on the exam and will change answers in a set time interval. There will be three rounds with five questions on an exam each. You gain a point for each question that you correctly answer. You can earn up to 10 dollars depending on how many points you have at the end of the three rounds. The teacher in this game is wearing a blue suit and is designed with advanced AI and vision capabilities such that they can perceive the world like real humans can. If the teacher catches you teaching, it's game over for that round and you will go on to the next round.

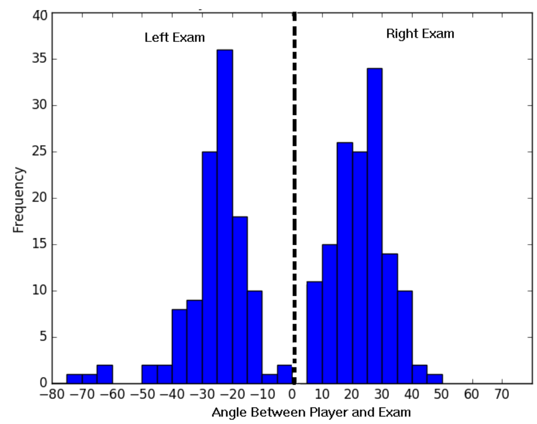


Figure 5: The angles by which players cheated off of the left or right exam.

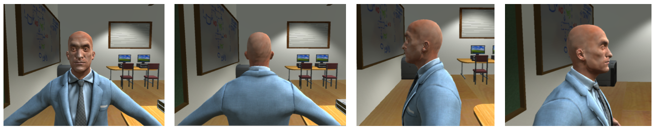
Results and Analysis

Using the data we have gathered during the game experiments, we plot several different variables against each other to draw conclusions on students' cheating behavior. We ignore the first round of data for each participant as the latter two rounds are far more likely to contain the players' intent and are not marred by first-time errors.A total of 255 cheating attempts were recorded (not counting the first round).

Peripheral Vision. We first examine the player's use of peripheral vision in order to cheat by inspecting the angle between the player's estimated gaze and the exam they are cheating off of (either the left or the right exam). The angles at which the player cheated off of the exams are shown in Figure 5. The number of cheating attempts made off of the left exam were 117 while the right exam had 138 in total. We refer to the human's field of vision (Bhise, 2011) depicted in Figure 4 to compare the angle between the player's central ray and the left or right exam to this diagram in order to determine which area of their vision the participants used to cheat.

For those who cheated on the left exam, a mere 2% cheated using their central vision. 24% of participants utilized their near-peripheral vision. The majority of the left attempts, 70% , cheated within the angle range considered to be mid-peripheral vision. The remaining 4% of these cheating attempts were conducted at an angle greater than 60 degrees. Similar results were found for the cheating attempts done on the right exam. 0% used their central vision on this side while 38% relied upon their near-peripheral vision. The remaining 62% all took place under the player's mid-peripheral vision.

Instead of staring directly at the other students' exams, the subjects chose to keep the exam they were cheating off of to the side of their vision. The reason for this result could be the effect of the player exhibiting signs of "sneaky" behavior. The player's cheating status is turned off or on simply by holding down the cheating buttons, which was made clear to the participants during the tutorial. Therefore, looking directly at another exam or not has no bearing on how quickly one can "stop" cheating. Because of this, we can say that the reason for this behavior is due to the player constantly keeping in mind the teacher, as the player exhibits signs of feeling wary of the teacher. By only "sneaking" glances at a nearby exam they are cheating off of, the student is trying not to be too "obvious" in their cheating. This action reveals that the



(a) Towards (b) Away (c) Left (d) Right

Figure 6: Appearances of the teacher at different relative orientations with the player.

student is letting their perception of the teacher's perception shape their own actions. The students exemplify the Theory of Mind: they are reasoning and making inferences on another's perception based on that person's behavior and are changing their own behavior accordingly (Dias et al., 2013).

Teacher's Orientation. The teacher in our experiment, in his pre-figured path around the room, pauses about every six seconds to rotate back and forth (as if he is scanning the room for signs of cheating) and turns his body like a normal person walking around a room would. Figure 6 shows the teacher's appearances at different orientations. We examine when players chose to cheat according to the teacher's orientation relative to the player by noting the angle θ by which the teacher sees the student (depicted in Figure 7).

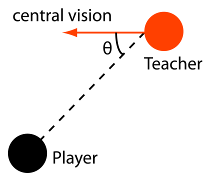


Figure 7: Angle between the teacher's central vision and the student.

According to Figure 8, students mostly cheated during the moments where the teacher was farther away from the student and when the student was on the outskirts of the teacher's perceived vision. Out of 255 recorded cheating attempts, only 7% of attempts were undergone when participants were within the teacher's central range of vision (and got caught by the teacher during these attempts). 12% of cheating attempts were done under the teacher's near-peripheral range of vision and 9% under the teacher's mid-peripheral range. The majority of cheating was split between when the student was within the teacher's far-peripheral range of vision (the dark purple points, taking up 34% of all cheating attempts) or when he was not facing the student at all (the black points, which make up 38%). When the teacher can see the student only with his far-peripheral vision or not at all, the player was able to be more certain that the teacher was not paying attention to him and therefore cheated the most during those moments.

Teacher's Position. Figure 8 also shows that more than half of all cheating attempts took place when the teacher's distance exceeded 3 meters, attesting to the player's feeling that, the farther away the teacher is, the "safer" the cheater is. Figure 9 shows further that students chose to initiate cheating when the teacher was located in areas that were farther away from them and did not feel safe enough to cheat when the teacher was not in sight. The moments in the teacher's path with the most frequent cheating attempts, at around 32% of all cheating instances, were located close to Area A, where the teacher was within the student's sight, was not relatively close to the student, and was moving in a clear path towards the back of the room. At this point, the student was able to cheat off of the left exam and keep the teacher within their line of sight. The least amount of cheating occurred around Area B, where the teacher was completely out of the student's range of vision. We see a brief peak in cheating when the

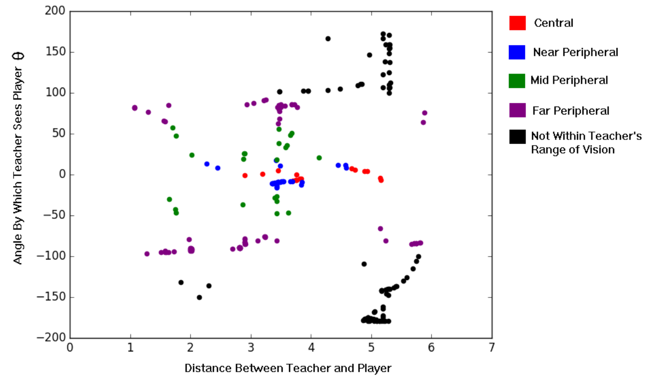


Figure 8: Each dot refers to an occurrence of cheating, plotted against the distance between the player and the teacher, and the angle by which the teacher saw the student.

teacher was close by but had his back turned to the player, in Area C. The player might assume they were safe at this point, thinking that the teacher would continue to walk away from them. However, the teacher turned around shortly after and walked by them again, moving back towards the front of the room. Cheating instances only became more frequent again, with around 9% of all cheating attempts happening, when the teacher had traveled a farther distance away in Area D.

The players' cheating patterns here reveal that students rely upon their perception of the teacher's perception to make judgments on the teacher's ability to spot them cheating. This explains why they choose to cheat only when they are able to see the teacher. It is also clear that the players used the animacy of the teacher to make predictions of the teacher's perception and behavior as they were more likely to cheat when he had his back turned or was walking away.

Discussion

Feedback and Observations. We asked the participants how they felt about the experiment after receiving their compensation. The general feedback from the players was that the game was "fun" and "interesting". They claimed that, during the game, they felt slightly afraid of the teacher model. From our observations, we noted that, during the start of the first round, the participants would be reluctant to look away from their paper at all once they saw the teacher. Only after we reiterated the rules of the game (that the student is not cheating unless the corresponding button is held down) did the players feel comfortable looking around the room. However, even still, very few players turned completely around to see where the teacher was when he was behind the student, even though they could have done so with no penalty. In reality, few students would turn all the way around to spot the teacher as this might appear suspicious. This attests to the participants taking the game seriously and that they performed as they would in an actual classroom.

Limitations. The participants' experience with virtual reality and computer games may affect their performance in our experiments. Most of our participants were students from the Computer Science major. Many CS majors are exposed to and regularly enjoy computer games, so they may have had a slight advantage in escaping cheating during the game sessions, compared to participants from a non-CS background. Furthermore, virtual reality headsets affected different partic-

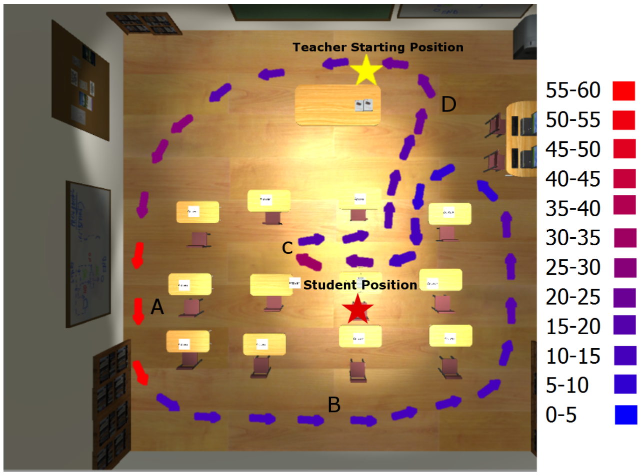


Figure 9: Cheating frequencies when teacher was at different locations along his path. Redness corresponds to the cheating frequency. Most cheating occurs when the teacher was at the far left. Refer to text for detailed description of the observations.

ipants differently, especially when some were wearing glasses or were just using a virtual reality device for the first time. As a result, some might have experienced slight discomfort with the virtual reality headset, perhaps leading to less ease in playing the game. We are also limited by the teacher's lack of realistic head movement. The teacher's torso and head move in the same direction throughout the game, which the player may or may not have realized as they were playing. Because of this, the results may be slightly varied from a real-life classroom setting.

Conclusion. In this study, we have verified our hypothesis about deceptive human behavior during an exam as the players (1) cheated most frequently when the teacher was turned completely away from them and (2) used their peripheral vision frequently to cheat off of other exams, showing that the teacher's animacy and orientation play a significant role in the student's likeliness to cheat and that their own judgment about "appearing" suspicious affected how they decided to cheat. By utilizing a virtual classroom setting and accurately tracking a user's behavior, we have also demonstrated how a novel virtual reality approach can be used for such experiments involving human behavioral observations, which can be further explored in other cognitive science research experiments. An interesting venue for future work is to use the human behavior data collected from virtual environments to train a realistic, human-like AI that can exhibit human deceptive behaviors. The application of new virtual reality devices that can accurately measure eye-tracking to this experiment would lend itself to the peripheral vision analysis as well. Furthermore, because students often cheat in collaboration with other students, our extension of this work will include a cooperative mode that allows two players to help each other cheat. We are also developing a quantitative method analysis of the player's cheating by establishing a metric to estimate the amount of visual attention the student is receiving from the teacher at any given point in time.

Acknowledgments

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