AN INSIGHT INTO DECISION MAKING

[a]MARTIN DOBIÁŠ, [b]JAROMÍR DOLEŽAL, [c]ALENA KLESALOVÁ, [d]JONÁŠ ERLEBACH

[a, c, d] Department of Economy, Management and Humanities, Faculty of Electrical Engineering, Czech Technical University in Prague, Prague, Czech Republic
b Czech Institute of Informatics, Robotics and Cybernetics, Czech Technical University in Prague, Prague, Czech Republic
email: [a]martin.dobias@fel.cvut.cz

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Abstract: Decision-making processes and decisions are the subject of long-term investigations by research teams and research centers all over the world. For centuries, various theories have been constructed, which first of all started out from the premise that during decision making we consider all the pros and cons, therefore that we behave logically and that our decision making is governed purely by reason (Lehrer, 2009). However, with the advance of scientific research, it has been determined and demonstrated that in decision making a role is played not only by rational behavior, but that another and no less significant role is played by our emotions and feelings (Bechara, 2004). For each correct decision, it applies that both sides of our brain should be used, and that it depends on the given situation as to when which side should take the lead. In connection with the development of eye-tracking technologies, new possibilities are constantly opening up for their application in practice. This study sets as its target a contribution to decoding the processes that take place precisely at the moment of decision making itself, whether it is possible to predict the choice or decision in advance, and whether it is possible to assess a certain characteristic according to the identified behavior with the aid of eye-tracking.

Keywords: Eye Tracking, Problem Solving, Strategy of Problem Solving, Prisoner Dilemma, Decision Making, Human Resources

1 Introduction

Observation of actual human behavior during decision making is relatively difficult, and as a result, psychologists since the time of Piaget and Kohlberg (Kohlberg, 1984; Piaget, 1932) have used hypothetical moral dilemmas when investigating moral decision making. This is usually a description of a certain situation or short story in the form of dilemmas, describing various manners of behavior, whereupon their 'rightness' is debatable at least to a certain degree.

The advantage of these dilemmas is above all the simplicity with which it is possible to alter their individual aspects, and then observe the effect of these adjustments on the evaluation of the described behavior. Originally psychologists assumed that moral judgements were based purely on a rational analysis of the situation, and as a result they concentrated only on those aspects that indicated whether a certain type of behavior was intentional or whether it was inadvertent. Joshua Greene with the aid of functional magnetic resonance imaging (fMRI) of the brain demonstrated that certain types of moral dilemmas activate parts of the brain connected with emotions (Green et al., 2001). This concerned situations in which a person is injured or killed by direct physical contact by a person who is acting with an intention to save other people. After this discovery there followed dozens of further studies which examined the role of emotions in moral decision making (Ekman, 1992) or (Bechara, 2004). On the basis of these findings, it is possible to state that if a dilemma evokes a stronger emotional reaction, people condemn the given behavior more.

As previous studies have already verified, with the aid of eye-tracking scientists are better able to understand visual attention and decision-making processes by recording to where the eye directed its gaze, observing pupil size, fixation and saccadic eye movements (Krajbich, Armel & Rangel, 2010). Regarding the fact that today methods for monitoring eye movements are ever increasingly being used for research purposes, the application of this technology in recent years has increased rapidly, especially in the field of behavioral economics and finance (Osborne & Rubinstein, 1994). Specifically, over the course of the last forty years, several studies e.g. (Peysakhovich, Vachon, Vallières, Dehais & Tremblay, 2016) have appeared which used tracking of eye movements in order to examine the correlations between eye movements and cognitive processes within various situations, such as reading, perception or visual search (Russo, 1975; Rayner, 1998; Pomplun et al., 2001; Kuo, Hsu & Day, 2009; Day, 2010). Whereas traditional experiments within a laboratory environment do not usually provide information about fundamental decision-making processes, technological advance has enabled the development of supplementary methods which can help us gain an insight into the 'black box' of perception and processing of information.

These systems enable the tracking of eye movements and the conversion of the user's direction of gaze into the co-ordinates of a computer monitor. For these reasons eye movement can be recorded by modern video recording devices, which have demonstrated themselves to be a more reliable method than mylab and verbal protocols (Majaranta et al., 2012). Eye cameras mediate information which people use before selection, and subsequently use for selection. This information may be supplemented by further parameters such as how long subjects observe an object or information, sequence, whether they select chaotically or are structured and systematic, whether they consider all the options, the speed or tempo they work at. On the basis of an analysis of these parameters it is subsequently possible to assess the consistency or inconsistency of behavior, or the tendency toward socially acceptable or unacceptable behavior. Our study is based on tracking of eye movements during decision making, solution and selection of variants of answers for the set dilemmas. The added value of eye-tracking consists in its deeper and more detailed understanding of how the proband perceives moral problems and how they actually solve them, whether the proband's behavior (selection of variant of answer) is actually in accordance with their moral stance.

2 Material and Methods

2.1 Participants

The pilot testing that took place within the period from the end of October to the end of November 2015 incorporated 27 subjects, of whom 21 were men and 6 women, who were students at the Electrical Engineering Faculty of the Czech Technical University in Prague. The average age of this group was 22.4 years. Further testing took place from October 2016 to January 2017. The target group in this case was managers and specialists at selected firms in various locations throughout the Czech Republic. This group incorporated 62 probands, of whom 31 were men and 31 women. The average age in this group was 36.3 years. The third group comprised psychologists and personnel consultants (HR specialists) and included 14 probands, of whom 5 were men and 9 were women. The average age of this group, which was tested during the course of May to June 2017 was 27.6 years. In all cases this concerned a population with normal or corrected vision (glasses/contact lenses).

2.2 Apparatus

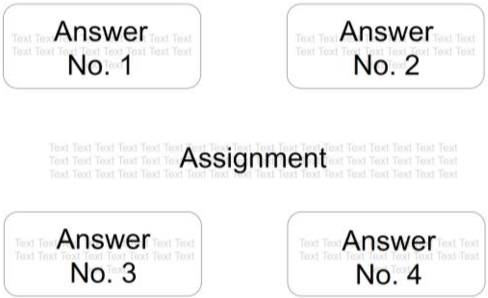
For measuring eye movements, we used a special eye camera, I4Tracking® Dist manufactured by Medicton Inc., which records the face of the tested subject and is capable of precisely detecting the location to where the subject focuses their view. With the aid of machine learning, the co-ordinates of the pupil and other points of interest are detected in the image. The eye tracker was calibrated on 9 points, and on the basis of the calibration measurement a geometric transformation was calculated, which subsequently converts the position of the pupils to the position of the view on the monitor. The device is capable of recording with a high image frequency. In the study we used a sampling frequency of 50 Hz, which enabled us to capture regular, 'observing' movements of the eyes. During the test exercises all eye movements were recorded, depending on what was displayed on the monitor. For the presentation we used the 24" monitor with a resolution of 1920x1200 at a distance of 60 cm.

2.3 Procedure

2.3.1 Schema of tasks

Within the framework of these tasks, five areas of interest were defined, and each contained a box with information (see Figure 1). The central part contained the described situation, and the boxes surrounding it (top left and right, bottom left and right) contained the individual answers.

Figure 1: Schema of the task



The proband's task was to select one of the offered answers. The experiments were carried out without a time limit. The assignment and answer variants were displayed on the monitor according to the above diagram. The proband should choose the answer that best fits his or her own, according to his/her assumed behavior in the given situation. The proband told the administrator the answer he had chosen and the administrator started the next task. The experiment was composed of four tasks, which observed moral dilemmas in decision making and selection of the variant of answer. Regarding the fact that only the task ‘Prisoner's dilemma’ was identical for all three groups the main conclusions will be based on comparative analyses relating to these data and results.

The task ‘Prisoner's dilemma’ (Kuhn, 2003):

‘Imagine that you are imprisoned with your accomplice, that you are held separately, and that you are interrogated. You can choose to testify against the other or to remain silent. The police have almost nothing against you, and if you both decide to plead not guilty, you will only get a suspended sentence. But if you help to convict your colleague, he will get ten years and you will go free. The same applies on the both sides. If you both choose to testify against the other, you will both get five years. How do you choose?’

Answers to choose:

I will remain silent and rely on my accomplice to do the same.

I will testify against my accomplice, because I think that he will testify against me.

I will testify against my accomplice, because I think that my accomplice will remain silent.

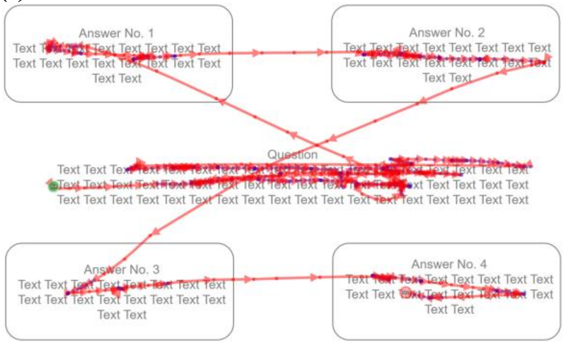
I will remain silent, because I think that my accomplice will testify against me and I will take the punishment.

2.4 Eye-tracker measures

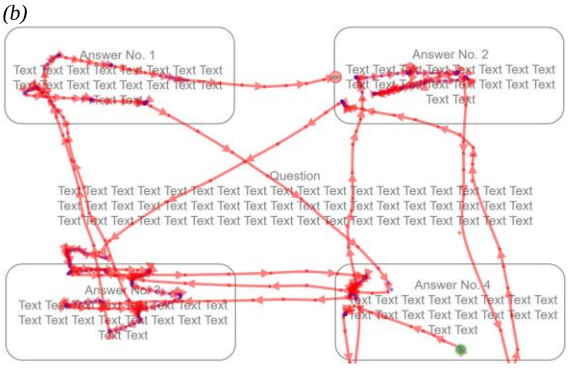
Eye movements are composed of fixations (relatively stable positions of the eyes persisting for longer than 200 ms) and saccadic movements (fast changes in between fixations). Visual information is obtained during fixations. Decision making and selection depends on the processing of the information. Patterns of eye movements reveal the object or information the eye has looked at, but from these patterns we can additionally say how long, and how often. The task is displayed on the monitor within the schema illustrated on the Figure 2. The path of the gaze is shown by the red line. The blue dots indicate the places at which the tested person looked for a longer time (“fixation”). Figure 2a shows a typical reading pattern: to read the assignment first and then to read each variant. Figure 2b shows an example of a decision making pattern: the gaze alternates between variants as they are considered.

Figure 2: Distribution of task and example of eye movements – reading pattern (a) / decision making pattern (b)

(a)



(b)



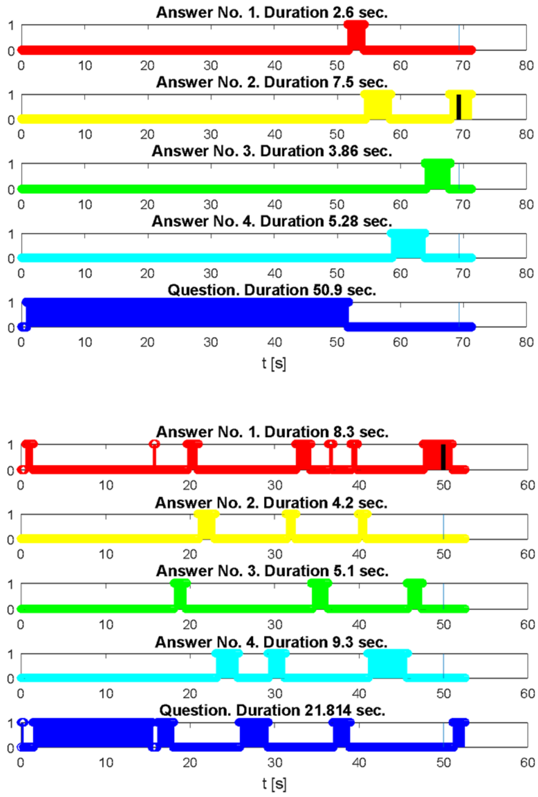
2.5 Data analysis

Altogether we defined five zones for the purposes of the analysis, so that we could easily identify the direction of the gaze and the length of holding in each zone. The zones corresponded on the one hand with the assignment and on the other hand with four possible answers located in rectangles in corners. The research didn’t focus on fixations and saccadic movements during the reading of the text but monitored just the gaze in the designated zones. See Figure 1. Data from the eye tracker were analyzed using Matlab (The Mathworks Inc.). From the acquired data for each moment based on the gaze coordinates we calculated the distributions of the gaze into zones. The vector of distribution of the gaze into zones was subsequently filtered through a moving window of 400 ms length. This step evened out the process, eliminated artifacts and filled in missing samples caused by blinking. This vector of gaze distribution into areas of interest over time and the proband’s chosen answer, represent primary data.

From this primary data secondary data was created by graphically representing the whole course of this experiment. The graphs depict the length of the holding of the gaze in the zones including all changes in the gaze, see Figure 3. Those graphs were subsequently assessed through expert analysis. Based on the comparison of all results, parameters were identified that described the proband behavior including the prediction of his competencies. The primary data - The distribution of the gaze into individual zones (areas of interest) over time - is shown in examples on the screen, where the zone (assignment and answer) at which the subject looks is systematically illustrated with the aid of color filling the relevant part of the graph.

In the left part of Figure 3 it is evident that the tested person first of all read the assignment (blue) and then the individual answers in the order of the first option (red), the second (yellow), the fourth (light blue) then the third option (green), before finally returning to the second option (yellow), which the subject then selected. At the moment of selection of the answer (a vertical line is shown), the subject was looking at precisely this answer, and according to the total time spent on the answers, the subject also looked at this option for the longest time. In this case it is possible to identify a very good level of decision-making processes – the person read each option (upon first glance) and did not return their gaze to the assignment. For comparison, the right part of Figure 3 illustrates a person who hesitated more (decided over a longer time) and returned their gaze repeatedly to the assignment.

Figure 2: Example of the distribution of the gaze into zones over time (Note: The individual variants of answer are presented in rows from the top down, the bottom row contains the assignment).



We found out that the subjects do not devote the same amount of attention to all the information, and use various strategies of selection and decision making. In order to determine the systematic or unsystematic nature of the approach to problem solving, we used the dispersion of the time devoted to the answers normalized by the number of characters of each of the answers. On the basis of a comprehensive analysis of primary data, we conclude that a systematic approach can be defined partially as thorough reading of the assignment from the beginning to the end, subsequent gaze at the variants of the answers, and final selection. It can also be defined on the basis of the number of gaze transitions, repeated gaze transitions to the assignment and to the chosen answer. By contrast, an unsystematic approach can be characterized in the case of a large number of short gazes, or overlooking of some of the variants of the answers.

Among other factors, the aim was to assess the behavior of the tested subjects, either as ‘hesitant shooters’ or in the form of stylization, when although they looked for the longest time at the variant they wished to choose, their choice was eventually of a ‘socially acceptable’ answer. On the basis of the first example, it is possible to state that the tested person in the first graph proceeds systematically in problem solving, is consistent, devotes a certain time to all the options (thus considers the alternatives) and chooses the answer to which he/she devotes the most time. For comparison, the person in the second graph proceeds less systematically, even chaotically in problem solving, returning repeatedly to the different options, and is less effective in the work, since in total he/she spends more time on this task.

Parameters that resulted from those analyses were calculated in the following way:

The first two seconds of each task were removed from the vector of distribution into zones, because completely at the beginning the gaze is directed either at the last place of the previous task or at the calibration that is done always before the first task. Subsequently the following parameters were calculated from the distribution into zones:

- The number of gaze transitions between all areas of interest divided by total time.
- Whether the subject chooses the option he/she looks for the longest time (logical yes/no).
- Whether the subject chooses the option he/she is looking at when deciding (logical yes/no).
- Repeated assignment reading – the number of gaze transitions from answers to assignment.
- Repeated answers reading – the number of gaze transitions from all areas to the selected answer.
- Time devoted to the selected answers divided by time devoted to all answers.
- Time devoted to the assignment divided by total time.

For an analysis of the strategy of decision-making processes we used as our key parameters the total time, the selected path, the number of steps or the number of steps within the framework of total time, how many times and how long the tested persons looked at the assignment, and the individual variants of the answers, including observation of the time at which they decided in favor of the selection of their answer. To examine differences between the groups we used a t-test. For visualization we used boxplots.

3 Theory

The prisoner's dilemma is whether to co-operate or betray (Kuhn, 2003). It appears to be a good choice to remain silent and not confess, but nobody can predict how the other prisoner will behave. The aim of the test was a deeper and more detailed understanding of how the tested persons perceive problem situations, in particular moral problems and how they actually deal with them, thus whether their behavior, in this case the choice of answer, is genuinely in accordance with their thought and contemplation. The test serves for an evaluation and assessment of the strategy of selection and decision-making processes, and also of how the proband approaches problem solving. The task was partly based on Kohlberg´s thesis that cognitive development, therefore the ability to think correctly/properly is a necessary condition for moral development. Cognitive ability codetermines the level of moral development that the individual achieves, but achievement of higher cognitive stages doesn’t necessarily mean a higher moral level. (Kohlberg, 1984).

We are able to identify from the eye movements the ability to take unequivocal decisions and discrepancy between eye movements and the choice of answer. Structured behavior and consistency, i.e. selection of the variant at which the proband looks for the longest time, or systematic contemplation of all the alternatives. On the basis of an identification of these parameters it is possible to predict reliably a tendency toward socially unacceptable behavior. The analysis of the time spent in each zone (area of interest) reflects the significance and importance of the given information for the individual proband. The distribution of the decision-making process before selection during decision making and potentially also after the decision is an indicator of the applied strategy of behavior. Following on from conducted studies and current discussions (Glaholt & Reingold, 2009), (Franco-Watkins & Johnson, 2011) and (Schotter, Berry, McKenzie & Rayner, 2010) we outlined hypotheses, the purpose of which was to contribute to further investigation and completion of observations relating to an insight into decision-making processes (how, when, what, the dynamic of observation, distribution of attention devoted to individual alternatives during selection, frequency of persistence of gaze, selection, time of decision making, measurement, duration of fixation).

3.1 Hypotheses

1. H1 selects the answer at which the proband looks for the longest time (frequency or persistence of gaze, or both are massively higher for the items which the subject eventually selects in decision making).
2. H2 selects the answer at which the proband looks when making the decision (moral decision making may be influenced by the fact of what we are focusing on at the moment of decision making (what the eye saw at the moment of answer).
3. H3 selects another answer (i.e. the proband selects an answer other than that which he/she looked at for the longest time, or at the moment of decision making).

4 Results and discussion

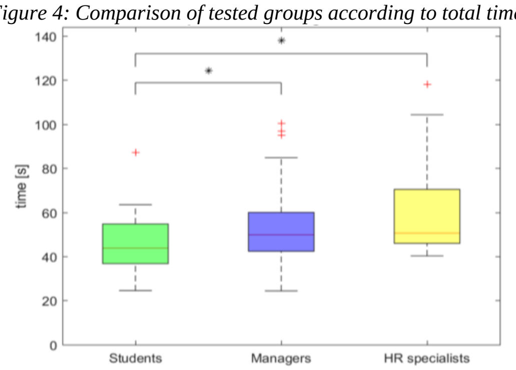
To compare the results and therefore the behavior of the individual groups we established three key parameters based on the completed analysis. 1) the total time spent on carrying out the task (see Table 1, Figure 4), 2) the number of steps during the process of completing the task (see Table 2, Figure 5), 3) The number of steps divided by total time (see Table 3, Figure 6). Due to the fact that these parameters have a wider validity and at the same time they relate to the hypotheses, it was possible to formulate this conclusion: If the behavior of respective groups differs according to the parameters, subsequently it is possible to conduct the verification of the hypotheses.

Table 1 : Comparation according to total time

Total time	MEAN	STD	p/ Students	p / Managers	p / HR specialists
Students	45.6096	13.6401	x	0.016963*	0.042717 *
Managers	53.9031	16.7301	0.016963*	x	0.28822987
HR specialists	61.0253	23.9799	0.042717 *	0.28822987	x

* p<0,05
**p<0,01

Figure 4: Comparison of tested groups according to total time



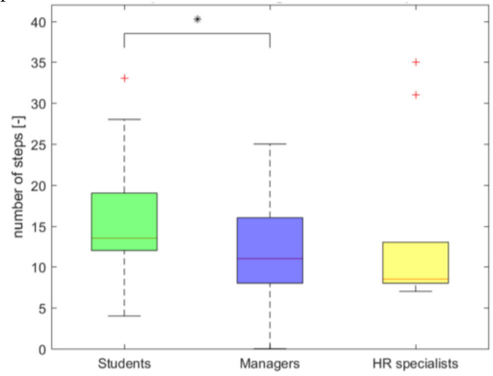
Within the parameter - total time spent on conducting the task – a significant difference (p<0,05) showed in the behavior of the group Managers and HR specialists in comparison to the Students' group. The difference between the group HR specialists and the Managers didn't show as significant.

Table 2 : Comparation according to number of steps

Number of steps	MEAN	STD	p/ Students	p / Managers	p / HR specialists
Students	15.9091	7.2303	x	0.038469*	0.350429
Managers	12.2581	5.3651	0.038469*	x	0.759578086
HR specialists	12.7143	8.8789	0.350429	0.759578086	X

* p<0,05
**p<0,01

Figure 5: Comparison of tested groups according to number of steps



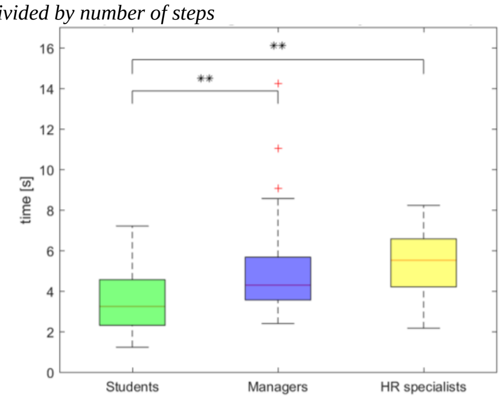
In the parameter Number of steps, the t-test helped to identify a significant difference (p<0,05) in the behavior of the Managers' group in comparison to the Students' group. The differences between the Students' group and HR specialists and then between the group Managers and HR specialists weren't shown as significant.

Table 3 Comparation according to time divided by number of steps

Time divided by number of steps	MEAN	STD	p/ Students	p / Managers	p / HR specialists
Students	3.4940	1.5914	x	0.003292**	0.002702 **
Managers	4.8365	2.1211	0.003292**	x	0.258759123
HR specialists	5.5435	1.6999	0.002702 **	0.258759123	X

* p<0,05
**p<0,01

Figure 6: Comparison of tested groups according to time divided by number of steps

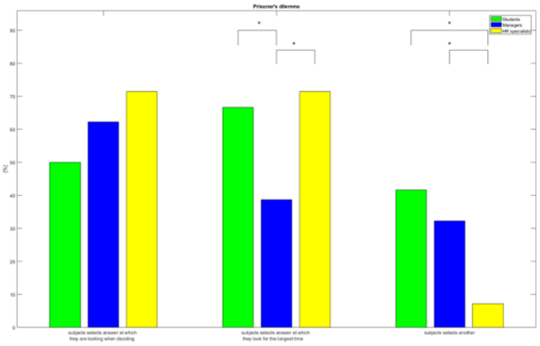


Regarding the number of steps divided by total time the t-test showed a very significant difference (p<0,01) in the behavior of the Managers' group and HR specialists in comparison with the Students' group. On the contrary the difference between the Manager's group and HR specialists group weren't shown as significant.

4.1 Verification of hypothesis

The students spent less time than the other groups on the solution of the task. The total time and the time when the subjects decided to answer was lower for the students. An interesting finding is that the students performed more steps than both other compared groups within a shorter time. This means that in comparison with the students the other groups spent longer on the individual answers and fixed their eyes. The students were quicker but skipped more with their eyes from the individual answers to others.

Figure 7: Verification of hypotheses – comparison of tested groups (Note.: Residual category selection of another answer is intended as a supplement (logical NOR) to the previous two options)



Our study confirms the findings relating to preferences of selection of the longest viewed variant, as concluded by e.g. (Bee, Prendinger, Nakasone, André & Ishizuka, 2006): On the basis of a comparison of the results of all sub-tests, we determined that this applies especially in the case of simpler dilemmas, therefore those in which we do not make a moral decision and at the same time we don't have to be thinking about the answer very long. (Kahneman, 2012), (Kahneman & Tversky, 1979, 1984). However, at the same time our research determined and demonstrated that the moment at which the probands decided had a decisive influence on decision making, and the selection of the answer. This conclusion is valid for all the sub-tests. This conclusion was confirmed as well by studies of scientists from the Department of Cognitive Science at University in Lund, University College London (Lund University, 2015) and California University in Merced (Pärnamets, Johansson, Hall, Balkenius, Spivey & Richardson, 2015), whose work, similarly to ours, demonstrates that our moral decisions can be influenced by what we are looking at, at the moment of decision making. The results show identically that human reactions are systematically influenced by what the eyes are looking at, at the moment of the decision. (S. Shimojo, Simion, E. Shimojo & Scheier, 2003).

The more complex the decision making in the dilemma, and the more moral behavior is required, the more often the probands choose a different answer (i.e. an answer other than the option at which they look for the longest time, and other than that at which they look at the moment of deciding). We drew this conclusion on the basis not only of the results of the 'Prisoner's dilemma' but also on the subtest 'Heinz's dilemma'. In both dilemmas, it was the group of students that most frequently did not choose either the answer they were looking at when deciding, or the answer they looked at for the longest time.

From the results in Prisoner's dilemma task shown on Figure 7 we draw the following conclusions:

- Half of all subjects choose the answer at which they look when making the decision even in case of complex and moral dilemma.
- The HR specials were more transparent than both students' and managers' groups.
- The managers' group has most often chosen a different answer than the one they were looking for the longest time.

We are of the opinion that this is most probably caused by a greater application of tactics or stylization for the choice of more socially acceptable variants of the answers. It is also possible to infer a concealment of the truth, an endeavor to show oneself in a somewhat 'better light', which is detected by the 'lie score' in personality tests. With the aid of eye movements, it is therefore possible to identify not only competencies of decision-making or problem solving better, more accurately and more effectively, but also to detect tendencies toward lying or socially unacceptable or dishonorable behavior, similar to (Fehr & Schmidt, 1999). If we assess the specific answers and behavior of the individual groups, then in all of them uncooperative behavior was the most frequently represented, i.e. answer no. 1 (top left): 'I'll remain silent and rely on my accomplice doing the same'. The managers, more often than the students, choose answer no. 2 (top right): 'I'll inform on my accomplice, because I think he'll also inform on me', while none of them chose answer no. 3 (bottom left): 'I'll inform on my accomplice, because I think he'll remain silent'. On the basis of the processed statistical models, it is possible to demonstrate the significance of individual parameters, on the basis of which we model competencies of decision making and problem solving. The presence/quality/degree of the given competency is demonstrated through a comparison of the individual proband with these models.

5 Conclusions

Overall, from the obtained results it is possible to state a finding that the set hypotheses were verified in the individual groups. The results of the study show that an analysis of eye movements may provide useful information about decision-making processes and the process of selection. Schemes of distribution of eye movements (their position, length, duration of fixation) may be used in order to obtain knowledge and information about patterns of thought.

For moral choice, what we fix our gaze on is significant. The processes that lead to a moral decision are reflected in our gaze. If the experimenter actively regulates what the individual sees, he can influence simple decisions with alternatives of almost the same valence. Eye Tracking can be used upon examining the individual differences in the process of decision making (working memory, selectivity of attention and choice), including determination of cognitive effort (Fehrenbacher & Djamasbi, 2017). It is possible to supplement the method of Eye Tracking appropriately with further physiological techniques such as electroencephalography or galvanic skin resistance. In addition to recording visual attention, EEG in connection with pupillometry enables measurement of cognitive effort from the electrical activities of the brain, whereas galvanic skin resistance measures excitement, exertion and stress through the change of moisture beneath the skin. A combination of these techniques may therefore provide a complete picture of the physiological activities of humans and thus offer detailed insights into decision-making processes. For example (Fulmer, 2014) made use of pupillometry in combination with advanced multimodal methods in a study on decision making concerning financial investments.

The method of eye tracking, as demonstrated by this study, can indisputably find its application in the identification or prediction of characteristics, aptitudes, abilities and competencies of humans. It can be used reliably for example in selections and evaluations of people, or during their development.

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Primary Paper Section: A

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