DETERMINING A STRATEGY FOR PROBLEM SOLVING BASED ON EYE MOVEMENTS

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Abstract: Success in solving problems depends on the strategy that we choose when looking for the right solution. In identifying strategies, we used records of eye movements during test problems, inspired by Raven's Progressive Matrices. The participants in research had to choose the right solution from 6 alternatives as part of 10 different problems. The results of the research showed that a strategy in which the person tested spends more time looking at the task itself (rather than the alternative solutions) is a more successful strategy. We can therefore predict success of resolution based on the ratio of time that we devote to the task before us to our interest in possible solutions.

Keywords: Eye tracking, problem solving, strategy of problem solving, Raven's Progressive Matrices

1. Introduction

We solve countless problems and tasks of various types every day. There are so many of them that we often do not even term them problems or tasks. However, all problems that we solve have one thing in common – the fact that there is a task, a problem to be solved, based on which we try to find the right solution. Psychologists, in the main, have for many years tried to discover which strategies used in problem-solving lead to the successful solution of tasks and problems or to increasing the likelihood of success. In our research, we decided to use eye tracking technology, to compare the characteristics of eye movements in successful and unsuccessful solvers and to find a strategy that increases the likelihood of success.

2. Method

The research method involved a specially set-up experiment in which the persons tested were sat in front of a monitor to solve test problems. We developed a special camera to measure eye movements, a camera that captures the face of the tested person and is able to precisely detect the place on which that person is training his/her sight. The coordinates of the pupils and other points of interest are detected in the image using machine learning. Geometric transformation is calculated based on calibration measurement and converts the position of the pupils to the position of view on the monitor. The equipment makes it possible to capture a high frame rate. We used a sampling frequency of 50 Hz in the research, which made it possible to capture normal "tracking" eye movements. All eye movements were recorded during test problems depending on what was happening on the screen.

A total of 62 people took part in the research – 31 men and 31 women – and measurements were carried out at various places in the Czech Republic from October 2016 to January 2017. The average age of the persons tested was 36.3 years. Participants were mainly managers and personnel officers from governmental and private companies.

The content of the test situations, and the task provided to the persons tested, was to solve 10 logic tasks inspired by Raven's Progressive Matrices, which were routinely used to test intelligence[1]. In each task, an incomplete image was shown on the left-hand side of the monitor. Part of the image was missing. On the right-hand side of the screen, 6 possible images were shown, of which only one was a perfect fit for the missing part on the left-hand side (Figure 1).

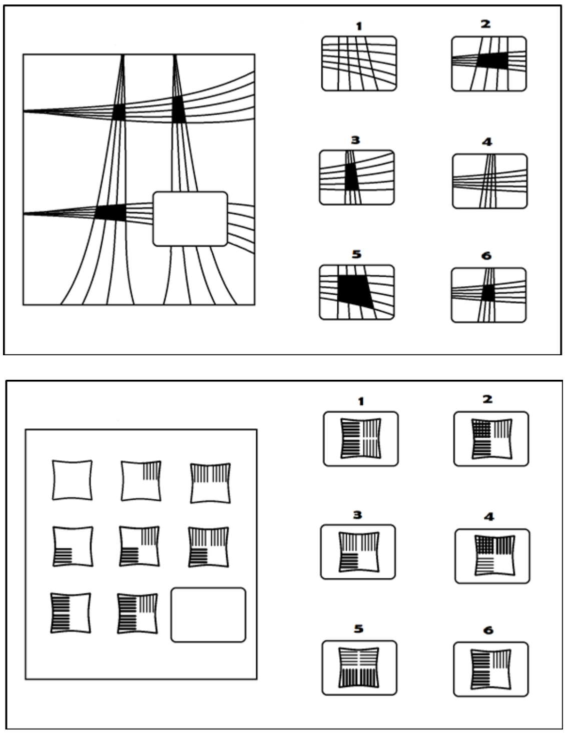


Figure 1: Examples of test problems

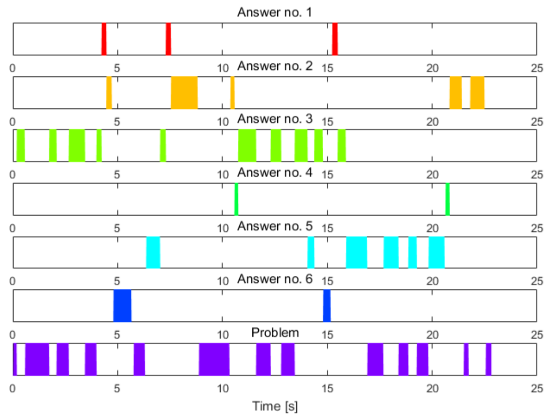
Persons were tasked with finding and choosing the one correct image that is to identify correct combination of partial subtasks. Earlier studies with eye-tracking have confirmed that the test persons identify these sub-tasks sequentially[2]. Individual problems varied in difficulty and there was no time limit placed on solving. Participants informed the experimenter present of their answers verbally. After stating their chosen image, the participant immediately moved on to solving another problem. Throughout the test part of the experiment, we recorded the eye movements of the participants and subsequently analysed these, with the aim of identifying the strategy of tracking (problem-solving).

In our analysis of eye movements, we concentrated on finding differences between successful and unsuccessful resolvers. We compared speed, fluency, structured nature, systematic nature and other selected characteristics. Two separate groups were therefore created during the analysis – successfully and unsuccessfully solved problems. We compared a total of 593 sub-problems (we had to omit a total of 27 problems from the original 620 measurements due to the participant's inability to answer or due to erroneous records of data). Of the 10 problems, we chose the 5 that best differentiated between correct and incorrect answers. We then compared the strategy of solving and the success rate / failure rate of solving for these 5 problems.

3. Results

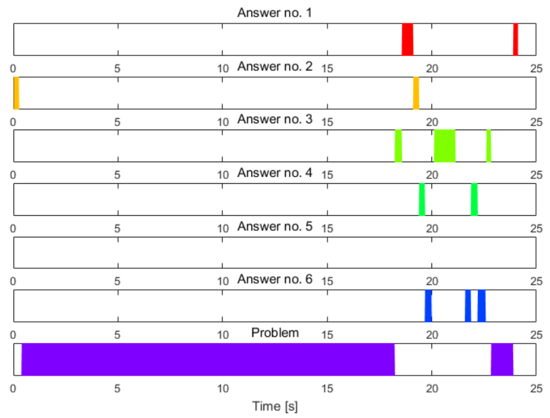
We identified the selected characteristics in relation to eye movements and the connection between these and successful/unsuccessful problem-solving using a t-test for two independent samples. One interesting finding was the significant difference ($p = 0.002$) in the ratio of the overall time spent solving problems to the time which participants devoted to the task itself.

The proportion of time that successful participants devoted to the task itself was higher than that recorded among unsuccessful solvers. This longer time "spent on the task" (in proportion to the overall time) is positively correlated to finding the correct answer, i.e. success in problem-solving. To provide an illustration of this, Graphs 1 and 2 show examples of our records of eye movements for individual measurement zones (the task itself and the 6 alternative answers on offer). Graph 1 shows the record of eye movements in an unsuccessful solver who only spent a relatively short time on the task itself (in relation to the answers) – 38 % spent tracking the task and 62 % tracking the possible answers.



Graph 1: Record of eye movements in an unsuccessful solver: time spent in individual zones

Graph 2 shows the eye fixation of a successful solver. The ratio of fixation on the right answer to other fixation here is considerably higher (a total of 83 % of the time spent looking at the task itself and only 17 % of time devoted to the possible answers).



Graph 2: Record of eye movements in a successful solver: time spent in individual zones

The actual record of eye movements and time spent looking at the task itself and at the alternative answers on offer therefore allows us to predict success, the selection of the right answer, without the solver actually having to mark that answer. A strategy in which people spend more time looking for the correct answer in the task itself and not in the possible answers is a strategy which is considerably more successful.

4. Discussion and Conclusion

Our findings and conclusions are confirmed by other researchers[3;4;5] according to which a successful problem-solving strategy in choosing one correct answer depends on the time that the problem-solver spends on the task itself.

Identifying strategies using eye movements has many advantages in comparison with other methods. The tested person need not know the real purpose and objective of testing and is therefore unable to intentionally influence the results. In classic psychodiagnostics, answers can often be purposefully distorted - the purpose of measurement is discovered and answers or responses to the stimuli are adapted with the aim of achieving the desired or the best result. Our testing tries to avoid precisely this possible distortion. It is very complicated, almost impossible, for the tested person to find out the purpose of testing and thus wilfully influence the nature of eye movements. After all, eye movements are automated responses[6]. The development of computer technology means that almost every portable computer is fitted with a camera that can be used to capture the user. It is from this that the potential for this form of measurement stems. Indeed, the tested persons could solve the test problems without the use of special hardware– it is enough for them to have their own computer with camera and Internet connection. Testing could therefore be conducted at any time and from any place. The potential of this type of testing also stems from the fact that it is not demanding on time.

The limitations or disadvantages of our method of testing lie in the need to use a camera and special software. Moreover, the surrounding lighting must be good when measurements are taken and the person measured must remain within the focus of the eye camera during testing.

Success in solving problems depends on the strategy that we choose when looking for the right solution. Our research showed that a strategy in which the person tested spends more time on the task itself (rather than on the possible solutions) is a more successful strategy.

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