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Data Analysis from Two-Choice Decision Tasks in Visual Information Processing

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***Abstract*— Data analysis is an important task in research. The present study focuses on the analysis of data sets from human eye movement experiments. The results of the experiments were analyzed according to two criteria – gender and age of the participants. The participants were divided into three groups, group 1: between 20 and 35 years, group 2: between 36 and 55 years and group 3: between 56 and 85. The results showed that 75% of the two-choice decision tasks were solved correctly. This trend was maintained among the participants from group 1 – respectively 75.4%. The participants from group 2 gave more correct answers – respectively 82.2%, but the participants from group 3 gave fewer correct answers, respectively, 70.2%. The average value of the response time indicator (of all participants) was 1455 ms. The participants' response time from groups 1 and 2 was shorter than the average (respectively, with 483 ms and 235 ms). The participants' response time from group 3 was longer than the average (respectively with 626 ms). The analysis outlined in this paper has the potential to be expanded upon. The movements of the participants' eyes are also documented during the experimental sessions and their answers to the tasks, and their reaction time. The information is saved in files with a particular structure (similar to the files from the experimental sessions). These files' data must be correctly modeled to be useful for further processing and analysis.**

***Keywords*—Data analysis; human eye movements; visual information processing; two-choice decision tasks.**

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I. INTRODUCTION

Different aspects of the generation of two-choice decision tasks based on visual stimuli [1]–[3] are discussed in various scientific publications. This is done in the study of decision-making processes in humans [4]. This field of science has been actively researched and developed in recent decades [5], [6]. The methods for analyzing the decision time in these tasks are also actively studied [7], [8]. For this purpose, various approaches based on neural networks have been developed and published [9, 10]. They are used to process the results after conducting the experimental sessions with the participants in the experiments [11]–[13]. These methods are also used in the analysis of decision-making processes [14], [15]. In these studies, various factors, such as age and gender and their influence on the decision-making processes are also analyzed [16], [17]. The data from these experiments are modeled and processed differently, for example, in relational databases and web services [18], [19]. In addition, the approaches to accessing this type of information are also different and are based on different technologies [20], [21].

For the research, specialized software was developed - DAT Library Explorer. It was used to process experimental data with additional functionality for exporting data to external files. Various aspects and software development methods are widely discussed in the scientific literature [22]–[26].

The participants in the experiment were grouped (conditionally) into three groups according to their age: between 20 and 35 years (group 1), between 36 and 55 years (group 2), and between 56 and 85 years (group 3). Preliminarily prepared sequences of frames (stimuli) were shown to each of the participants in the experiment. Each frame of each stimulus contains a specific number of points – 50. Depending on a predetermined level of coherence, each point can change its position between frames differently. For example, at a coherence level of 0%, the points change their positions chaotically, and at a coherence level of 100%, the points change their positions synchronized (arranged) in a specific direction. The coordinates and colors of the points for

each frame are preset. Each stimulus contains a sequence of 100 frames. The duration of one experiment (one experimental session) is 140 stimuli. Each stimulus is a kind of "visual" task for recognizing the direction of movement of a set of points, respectively left (Fig. 1) or right (Fig. 2). The parameter that changes is the offset of the center of the set of points from the center of the screen. This parameter has predefined seven levels, with values of 20, 40, 60, 80, 100, 120, and 140 pixels, respectively. Each experimental condition is called a variant. Each variant is repeated ten times (within one experiment).

Fig. 1 Stimulus cl606.bin (movement = combined, orientation = left, displacement = 60, variant = 6)

Fig. 2 Stimulus cr807.bin (movement = combined, orientation = right, displacement = 80, variant = 7)

According to the type of movement, four types of stimuli are distinguished, respectively combined: flicker, motion, and static. Static-type stimuli are a collection of 50 fixed points (stored in one frame). For other types of movement - combined, flicker, and motion, the set of points changes depending on the rule of offset relative to the screen center. For example, all points are shifted at the same distance in a certain direction, or all points are rotated at a certain angle to the center of the screen. In the type of combined movement, the points move depending on the direction of their orientation. In the flicker motion type, one-third of the points are generated at new positions. In motion type, 36 of the 50 points move away from the center of the set, and the other 14 points move in a random direction. The purpose of these "visual tasks" is that the participants in the experiment should recognize the correct direction of the stimulus.

Each stimulus is stored in a separate file. The stimulus files have specific names. These names also provide additional information on some of the characteristics of the respective stimuli. The convention for naming a stimulus file is movement, orientation, displacement, and variant (.bin).

II. Material and Method

Each participant in the experiment can answer any visual task (stimulus) before visualizing all its frames during one experimental session. The participant can stop displaying the current stimulus by pressing the left or right mouse button, depending on the recognized direction of the stimulus. This is an important feature in this type of experiment, and therefore the application that visualizes the stimuli also saves the decision-making time (i.e., reaction time) of each participant for each stimulus. The sequence of 140 visualized stimuli we call an experimental session.

Participants' answers are also stored during the experimental sessions. The information is stored in text files with the extension ".dat" (short for "data"). These files have a specific file structure. Each DAT file contains data for one experimental session per participant. The information stored in the DAT files and the structure of these files are presented in detail in Table 1.

TABLE I
Specification of The Structure of DAT Files

No	Parameter	Type (domain)	Description
1	StimulusNumber	Byte {0,.., 255} Values {1, 2, ..., 140}	*The number of the stimulus*. The sequence number of the stimulus to be visualized (within the current experimental session).
2	StimulusName	String	*The name of the stimulus.* They consist of the abbreviations of the parameters: *Kind Movement*, *Orientation*, *Displacement*, and *Variant*
3	ReactionTime	Integer	*The participant's reaction time* (decision-making time for the specific stimulus).
4	Response	Byte {0, .., 255} 0 : left; 1 : right	*The participant's answer* (for the direction of the stimulus).

The name of each .dat file contains additional information that conforms to the file naming convention for this file type:

GroupNumber_SubjectInitials_ KindMovementAbreviation_Try.dat

GroupNumber is an index of an age group depending on the participant, *SubjectInitials* are the initials (first letters of the names) of the participant, *Kind Movement Abbreviation* is the abbreviation of the type of movement and *Try* is another experience of a participant (with this group of stimuli). Since there are ten variants for each group of stimuli (*c*, *f*, *m* or *s*), for each variant there are seven predefined conditions (displacement), and each stimulus is visualized twice, the total

number of visual tasks for one experimental session is 10 * 7 * 2 = 140.

The information for all experimental sessions is stored in different files. This way of organizing the data is not convenient for analyzing the information, as the data is in an unstructured format. Therefore, we combined all the data into a common data set with the following relational structure:

Experiments {

Group, Participant, Sex, Age, Try, Row, MovementKind, Direction, Displacement, Variant, Reaction, Response, Stimulus }

The data structure modeled provides opportunities for more convenient processing and analysis of the information from the experimental sessions. The study of the results from all experimental sessions is presented in the next section. Other results from this experiment were published in [27].

The experimental results were summarized and processed using the DAT Library Explorer application. It was developed for this study. With this application, the data can be sorted, filtered, and exported to external files and programs, such as those that support the comma-separated value format – CSV (Fig. 3).

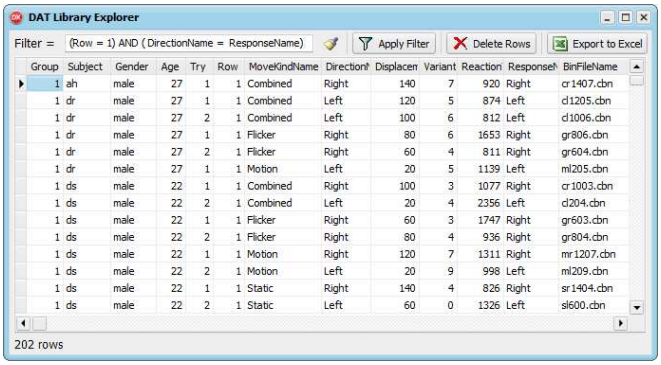

Fig. 1 Working session with the DAT Library Explorer application

TABLE II
SUMMARY DATA FROM THE CONDUCTED EXPERIMENTS

No	Participant Initials, Sex	Group	Age	Number of Stimulus	Number of Sessions	SUM Reaction Time (ms)	AVG Reaction Time (ms)	Correct answers	Incorrect answers
1	AH (M)	1	27	559	4	355 426	635.82	427	132
2	DR (M)	1	27	1120	8	1 160 843	1 036.47	936	184
3	DS (M)	1	22	1119	8	962 005	859.70	891	228
4	HIM (M)	1	23	1259	9	1 367 905	1 086.50	981	278
5	KAP (F)	1	32	1120	8	1 883 687	1 681.86	690	430
6	KAT (F)	1	30	1118	8	1 050 098	939.26	894	224
7	KR (F)	1	28	560	4	619 259	1 105.82	373	187
8	MNI (M)	1	20	1120	8	1 475 577	1 317.48	966	154
9	RSK (F)	1	34	1258	9	728 881	579.40	817	441
10	SGN (F)	1	23	1119	8	998 342	892.17	901	218
11	TOD (M)	1	20	1119	8	976 775	872.90	689	430
12	TT (M)	1	21	1119	8	731 141	653.39	926	193
13	IHR (M)	2	37	1118	8	1 176 325	1 052.17	922	196
14	IIL (M)	2	41	1120	8	1 942 406	1 734.29	958	162
15	KIR (F)	2	40	1120	8	1 127 375	1 006.58	901	219
16	LP (F)	2	52	1120	8	1 200 091	1 071.51	982	138
17	MI (F)	2	48	1120	8	1 215 833	1 085.57	984	136
18	MSM (F)	2	44	1118	8	1 575 371	1 409.10	969	149
19	PT (F)	2	51	1120	8	1 716 101	1 532.23	934	186
20	SIM (M)	2	36	1120	8	1 653 275	1 476.14	962	158
21	TST (M)	2	41	1119	8	843 761	754.03	879	240
22	VEL (M)	2	41	1119	8	1 201 737	1 073.94	716	403
23	ATH (F)	3	62	1120	8	2 683 231	2 395.74	942	178
24	DD (M)	3	68	1120	8	3 581 897	3 198.12	958	162
25	DEN (F)	3	74	1373	10	2 843 948	2 071.34	1145	228
26	DZ (M)	3	84	1113	8	2 185 392	1 963.51	706	407
27	GB (M)	3	83	840	6	1 142 188	1 359.75	360	480
28	KA (M)	3	59	1119	8	1 374 257	1 228.11	932	187
29	LBB (M)	3	73	279	2	238 308	854.15	251	28
30	LYD (M)	3	57	1399	10	3 745 091	2 676.98	755	644
31	PAV (F)	3	73	1219	9	1 999 361	1 640.16	826	393
32	PM (M)	3	62	1120	8	2 268 227	2 025.20	909	211
33	REN (F)	3	73	1397	10	4 214 642	3 016.92	619	778
34	SNJ (F)	3	64	1120	8	1 681 755	1 501.57	953	167
35	VAG (F)	3	73	1256	9	3 923 579	3 123.87	809	447

III. RESULTS AND DISCUSSION

In the present study, we analyzed two indicators: the percentage of correct answers to all answers and the reaction time when deciding by the participants (when "solving" the visual tasks). For both indicators, the results were analyzed, both depending on the gender of the participants and their age. Table 2 shows the summary data from experiments that were conducted with 35 participants. The participants were divided into 3 groups according to their age (as described at the beginning of section 2 in this paper).

To analyze the results, it was necessary to summarize Table 2 according to different criteria. For each group, the values for minimum, maximum, total, and average were calculated, respectively. Table 3 shows the summarized average data from the conducted experiments, respectively, for all participants, for women, for men, and for age groups.

TABLE III
THE SUMMARIZED AVERAGE DATA FROM THE CONDUCTED EXPERIMENTS

Group	Age	Number of Stimuli	Number of Sessions	AVG Reaction time (in ms)	Correct Answers	Incorrect Answers	Correct Answers (%)	Incorrect Answers (%)
Total	46.94	1 093.11	7.83	1 454.62	824.66	268.46	75.81%	24.19%
Female	50.06	1 141.13	8.19	1 565.82	858.69	282.44	75.55%	24.45%
Male	44.32	1 052.68	7.53	1 360.98	796.00	256.68	76.04%	23.96%
Group 1	25.58	1 049.17	7.50	971.73	790.92	258.25	75.14%	24.86%
Group 2	43.10	1 119.40	8.00	1 219.56	920.70	198.70	82.25%	17.75%
Group 3	69.62	1 113.46	8.00	2 081.19	781.92	331.54	71.48%	28.52%

The row "*Total*" of Table 3 shows the average values of the data for all participants in the experiment. These values are distributed in columns as follows: the average number of stimuli, the average number of sessions, average reaction time (in milliseconds), the average number of correct answers, the average number of incorrect answers, percentage of correct answers, and percentage of incorrect answers. The rows "*Female*" and "*Male*" show the average values of the data when the participants are grouped according to their gender. The rows "*Group 1*", "*Group 2*", and "*Group 3*" show the average values of the data when the participants are grouped according to their age.

Fig. 4 Answers – Total

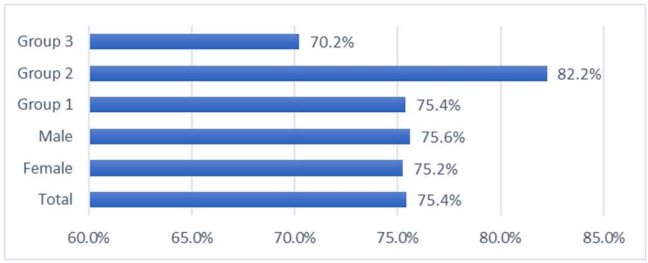

Fig. 5 Answers by groups

From the summarized data for all participants, it can be seen that in 3/4 of the visual tasks (stimuli) the correct answers are recognized. This is approximately 75% of all cases (Table 3 and Fig. 4). This ratio is maintained in the distribution of participants depending on their gender. The correct answers in this case are 75.2% for women and 75.6% for men. These results can be seen in Table 3 and Fig. 6. It can be concluded that in the experiments conducted related to the correct determination of the visual direction of the stimuli, gender does not influence the correct decision.

In grouping the participants by age, the ratio of 3/4 correct answers to 1/4 wrong answers (i.e., 75% versus 25%) is maintained only in Group 1. These are the participants aged between 20 and 35 years. The correct answers in this group of participants are 75.4%, which can be seen in Fig. 7. In Group 2 there is an increase in the correct answers to 82.2% (Fig. 7). In Group 3, however, there was a decrease in the average number of correct answers to 70.2%.

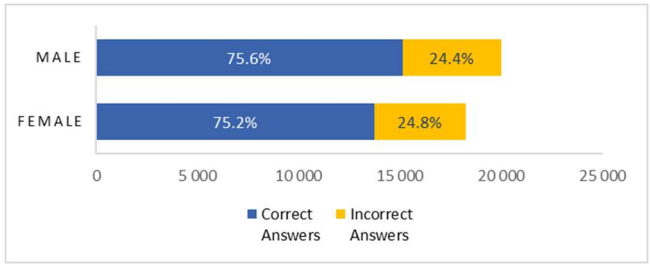

Fig. 6 Answers by sex

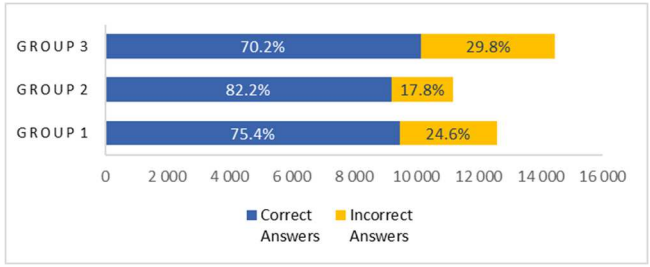

Fig. 7 Answers by age

We can conclude that the percentage of correct answers of the participants from group 1 (between 20 and 35 years) is comparable to that of the correct answers given by all participants (Table 3, Fig. 5). In age group 2 (participants between 36 and 55 years) there is an increase in the number of correct answers (on average by 9% more) compared to the average number of correct answers for all participants. In contrast, in age group 3 (participants over 56 years) there is a decrease in the average number of correct answers. In this case, the correct answers are 7% less than the correct answers for all participants. This ratio is shown in Fig. 5. The values show that in the groupings "Total", "Female", "Male", and "Group 1" the results are almost identical. In Group 2 there is an increase in the number of correct answers as opposed to a decrease in the number of correct answers in Group 3.

The analysis of the values of the decision time (reaction time) showed that there is a difference in this criterion, both in terms of gender and in terms of the age of the participants in the experiment. The average decision time was 1455 milliseconds (row "Total" in Table 3). The values of this indicator vary the most in Groups 1 and 3. In Group 3 the decision time is higher than the average by 43%, and in Group 1, the decision time is less than the average by 49.6% (Table 3 and Fig. 11). When grouping the participants by gender, the decision time between the two groups is commensurate; respectively, the average decision time for "Male" is 1361 ms and for "Female" is 1566 ms. The average decision time of the "Female" group was 205 ms longer than the average decision time of the "Male" group (Fig. 8).

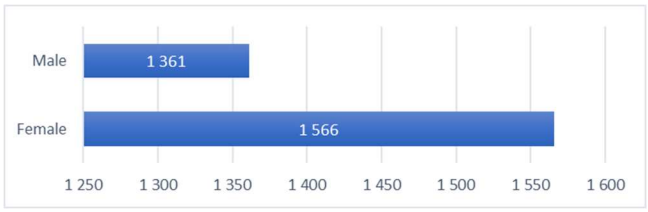

Fig. 8 Reaction time by sex (in ms)

When grouping the participants by age, the values of the decision-making times for each of the groups in relation to the others are as follows: 972 ms / 1220 ms / 2081 ms. The difference in the values of this indicator for Group 1 and Group 2 is approximately 248 ms. This value is commensurate with the difference in decision time between the "Male" and "Female" groups. However, the absolute value of this indicator between groups 3 and 2 is 862 ms. This value is much larger (on the order of 3.48 times) compared to the difference for the same indicator between groups 1 and 2. It can be concluded that with the age increase, decision-making time increases significantly (for this particular type of visual task) (Fig. 9).

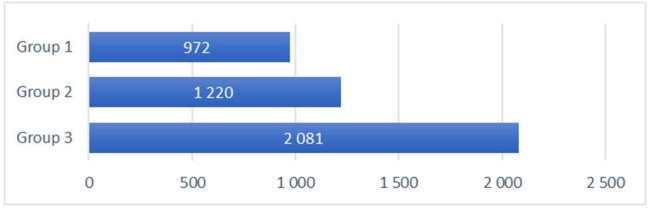

Fig. 9 Reaction time by age (in ms)

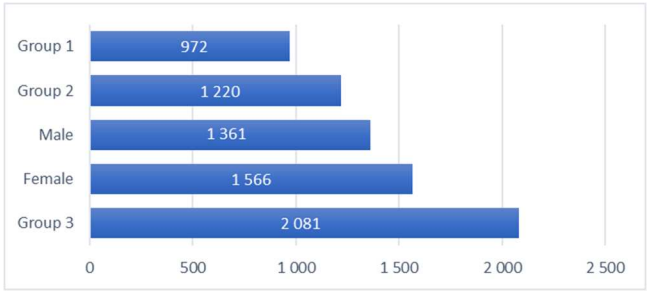

Fig. 10 Reaction time by groups (in ms)

Fig. 10 shows (in order) the decision-making times, both when grouping participants by gender and by age. Fig. 11 shows a similar arrangement of decision times, which, however, is compared to the average decision time for all participants. Based on the obtained results, the following conclusion can be formulated: the time for decision-making in this type of visual tasks depends, in direct proportion, on the age of a participant and not on their gender.

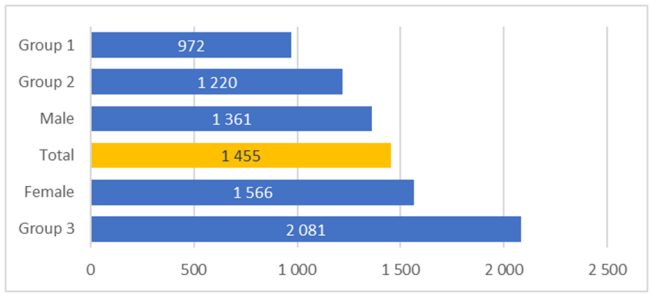

Fig. 11 Reaction time – total (in ms)

IV. Conclusion

The present study was related to analyzing experimental data generated during experiments in which participants solved visual tasks with two possible answers. The experiments were conducted as follows: visual tasks (stimuli) were shown to a certain group of participants. The answers that the participants gave for each task were stored in files with a specific structure. The target group of participants was divided first into two groups according to the sex of the participants and then into three groups according to the age of the participants. After analyzing the experimental data, it was found that: the ratio of correct answers to incorrect answers (given by all participants in the experiment) is 75% (correct answers) to 25% (incorrect answers). Similar results were found when grouping the participants according to their gender - respectively for "*Male*" 76.04% (correct answers) to 23.96% (incorrect answers) and for "*Female*" 75.14% (correct answers) to 24.86% (incorrect answers).

These results showed that in this type of visual tasks the gender of the participants did not affect the quality of the answers. When the participants were grouped according to their age, the analysis of the results showed that the ratio of correct to incorrect answers was comparable to the average only for the participants from Group 1 (between 20 and 35 years). This ratio is as follows: 75.14% (correct answers) to 24.86% (incorrect answers). In Group 2 (participants between 36 and 55 years) an increase in the percentage of correct answers was found – 82.25% (to 17.75% incorrect answers). In Group 3 (participants between 56 and 85 years), however, it was found that the average number of correct answers is lower than the average number of correct answers for all participants in the experiment - respectively 71.48% (to 28.52% incorrect answers).

Regarding the decision time criterion, it was found that the average decision time for all participants in the experiment was 1455 ms, respectively. The values of this indicator vary the most in the participants from groups 3 and 1. In Group 3, the decision time reaches values higher than the average by approximately 43%. In Group 1, however, the decision time is significantly shorter and reaches values lower than the average by approximately 49.6%. The analysis of the decision time when grouping the participants by gender showed that

the decision time for women is on average about 205 ms longer than for men.

The research work presented in this paper can be further extended. During the experimental sessions and the answers to the tasks and the participants' reaction time, the movements of their eyes are also recorded. The data is stored in files with a specific structure (similar to the files from the experimental sessions). The data from these files need to be appropriately modeled so that they are convenient for further processing and analysis.

V. Conclusion

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