Predictions of age and mood based on differences in saccades parameters.

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Abstract. We have measured saccades of 12 subjects in age below 30 (younger adults) and over 60 (older adults) during musical sessions with energetic and relaxing music. We wanted to check if saccade parameters are sensitive to emotions caused by music and if so, check if there ability to distinguish and classify those parameters to one of defined group of Age (young/old) or group of Mood (energetic/relaxed) induced by the music. We used combination of different types of filters and classifiers from WEKA [5] in search of possible correlations between saccade parameters and characteristics of respondents. Results showed statistical changes between age groups in the latency (23.6% of difference) and in the pupils size (16,6% of difference), both found significant ($P < 0.0001$). In case of Mood, results showed changes in the group of younger adults in the latency ($P = 0.4532$), the amplitude ($P = 0.0001$) and for the average velocity ($P = 0.0048$). Prediction of age group showed the accuracy of of 91.4 %, in case of Mood groups 97%. For both types of groups, best predictions were obtained by the Random Forest and the Multilayer Perceptron.

Keywords: eye moves, saccades, eye tracking, eye move computations, brain computations, human features, emotions, moods, age, machine detection and classification

1 Introduction

We investigated possible changes in parameters of saccades, caused by emotions induced by music listening, among people who are different in the age. Music has a fundamental effect on humans. It was shown that during motor activity, music optimizes arousal, facilitates task-relevant imagery and improves performance in simple and repetitive motor tasks, like saccadic eye movements [12]. Music also has significant effects on Autonomic Nervous System (ANS) especially on heart rate, respiration rate, blood pressure and also on pupillary response controlled by ANS. In states of relaxation, limbic moves (thus also eye moves), theoretically should be slower and less rapid, while in state of arousal, faster and more dynamic. Neutral music significantly reduces eye movement activity, when they listened to music subjects exhibit longer fixations, more blinks and fewer saccades [18]. One of the basic types of eye movements is the saccade which can be described as rapid, ballistic movement of the eyes that rapidly change the point of fixation [4]. Saccades are varied in terms of visual angle, from small saccades made when we read, to longer movements when we look around ourselves. The more points are deviated from each other, the shorter is the fixation and saccades are more dispersed [6]. Saccades occur involuntarily whenever the eyes are open, even they are fixated on a target, but can be also elicited voluntarily [4]. Human eyes make saccades when watching available field of view, fixing on interesting elements of the surroundings. The source of this phenomenon comes from the fovea, which receives input from only a small portion of the visual field. In order to view a complex scene, the fovea must be moved to new fixation locations very often [9]. The speed of saccade cannot be controlled - the eyes move as fast as they are he highest speed at around 15° [1]. Saccades are very common in the functioning of the oculomotor system, occurs up to 173,000 times per day [17]. Saccade generation and triggering seems to be very sensitive as many areas of the brain are involved in this process. The results of studies on selective effect of age on oculomotor performance states, that in neurologically normal individuals, senility is serving to slightly increase saccade latencies [15]. Older adults have longer latencies in a variety of motor tasks (i.e. aimed hand movements) [9], [15]. The general slowing hypothesis, suggests that slowing of information processing is increasing with age and it is an overall slowdown, not connected with any of particular tasks. [9]. It seems to be true, as specific task may also be affected by other age related factors. In case of saccade trials there is an evidence indicating that as people becomes older, inhibition of inappropriate response becomes less effective, as well as suppression of irrelevant information. In addition, depression or anxiety both of which are common in older people and increasing with age, may also interact and impair or alter saccadic task performance [15]. However it also seems that older adults produce saccadic eye movements in fundamentally the same way as younger adults. It may suggest that mechanism which triggers and controls the saccade may not be degraded with progressing age [9]. In terms of pupil size, few researches states a significant difference between age groups. The rate of change of pupil diameter decreases with age from 0.043 mm per year at the lowest luminosity level to 0.015 mm per year at the highest [3], so the average pupil size of subjects between 20-30 years old is ~ 6.9-6.5 mm, while pupil size of adults between 60-70 is ~ 5.1-4.8 mm [10]. In case of pupil size, it has been found that larger dilations were predicted for emotions connected to arousal or tension in case of musical excerpts rated as inducers of these emotional states. Overall, findings suggests a complex interplay between different influences on pupillary responses to the music [2].The experiment described in this article, was conducted to determine possibilities of prediction of age and mood measurements from saccadic parameters, in context of emotions induced by music listening - which is not well studied and understood yet.

2 Methods of the experiment

12 subjects, different gender and aged 23 to 67 divided into two groups of young (six subjects in age between 23-30, mean 25.75, +/- 1.47 SD) and old adults (six

subjects in age between 60-67, mean 64.75, +/- 1.47 SD). None of participants indicated any illness, nor take any medicine. Each of participant declared before the study, that music was capable of exerting an emotional effect on him - relaxing and stimulating. It can be said, that only people who declared emotional sensitivity to music took part in the experiment. Subject's eyes movement during saccade sessions were measured by eye tracking device The Eye Tribe ETI1000 (60Hz). During each session all subjects viewed IBM Think Vision 6636 15" LCD square display (1024 x 768 px) from distance of 60 cm in the sitting position.

During the experiment visual elements were displayed on the screen and managed by dedicated application. At the beginning of each trial, subject was viewing a fixation point - the green ellipse located in the middle of the screen and that was the primary position of the gaze for each saccade trial. To initiate saccade measurement process, subject had to keep eyes on the fixation point for randomly selected time period between 1000 and 2000 milliseconds. Eye movements were measured in response to fixation and target points were switched sequentially on and off. The target always appeared in the same horizontal location of the fixation point and has the same shape of the ellipse. Schema on Fig.1 presents the model of the saccade trial.

Fig. 1. Model of the saccade trial

Subjects were asked to perform saccades from fixation point to the appearing target. Before each saccade attempt, application set a random break period (0.5, 1 or 1.5 second) performed to help release gaze tensions and also to avoid eye to start moving rhythmically. Thus, subject never knew exactly when another trial starts. When measurements started, fixation point disappeared. In the same moment, target of the saccade appeared randomly on one of sides of the screen. This "Gap Effect" measurement model introduced by Saslow (1967), assumes that the removal of a visual fixation point shortly before the appearance ofa peripheral target results in shorter latencies for saccades directed at the target, than when the fixation point remained on. As stated previously, according to other researches [11, 12], latency is the main difference in saccade parameters between different age groups and older people are less able to suppress saccades during active fixation and have reduced effect of fixation point offset relative to younger people. This effect of reduced fixation inhibition is beneficial for older people in terms of decreased length of latency [15]. The Gap model shows latency adjusted by this phenomenon, thus shows reduced differences in response time between both age groups.

Before the experiment, subjects had to choose two pieces of music they knew and they could say that it most affects their emotions. It was told, that first piece should make subject energetically stimulated, the second one should make subject calmer and put him in quiet or touched mood. Subject could find and play any pieces of music. Participants choose their own pieces, because perception of music is very subjective and it is difficult to find pieces which could influence every participant. Musical piece was listened to on closed headphones before sessions of Energetic and Relaxed mood. It has been also determined that the respondents will choose music they know and like, as pupillary responses should modulate less strongly when track is particularly liked [2], thus should reduce differences between different mood groups.

Experiment was conducted in different 3 sessions of saccades recording, for "music off", energetic and relaxing music. Each session type was expressed in numeric value related to the assumption of object's stimulation: 0 for "music off", -5 for relaxing, 5 for energetic music. Each session contained preparations and/or music listening, device calibration and saccade measurements procedure. Session started only when device was perfectly calibrated, which was determined programmatically. Music was played before, not during the saccade measurements to avoid interactions with Autonomic Nervous System [8]. After each session subject's mood was noted in questionnaire. Mood was measured by object himself in scale between -5 and 5, where 0 is the neutral state, -5 is the most calm and 5 is the most excited. Each of sessions contained 3 sequences of 10 saccade tries, each session lasted about 15 minutes. Subject himself decided when to start another sequence of saccade measurements, so he could rest between them. Subject also decided, when to stop listening to music. It was said that it should be a moment when he felt the music had a profound effect on him.

3 Computational Basis

The output from the eye-tracker contains raw data of eye properties and coordinates measured in frequency of 60Hz. Data log of each saccade was analyzed by application which calculated saccades latency, duration, amplitude, average velocity, peak velocity and average pupil size.

The latency was measured as period between fixation point disappearance and start of the saccade. Start of the saccade was set as the moment when gaze velocity (deg/sec) reached over the threshold velocity determined for particular record. Duration of the saccade was determined as the period, starting when gaze velocity (deg/sec) was over velocity threshold and finish when fell down below it. Threshold velocity was calculated from all subsequent frames of the record (including latency period) by dividing the maximum speed by the average speed. Additionally application detected and recorded the moment when subject's gaze focus left the fixation point and when it reached the target (which served as additional validation). The amplitude was calculated based on the visual angle. The visual angle of the image on the retina can be calculated by measuring the angle subtended by the object outside of the eye [11]. Thus, the visual angle can be calculated as the arctangent of tracked distance of subject's eyes position from fixation point (b) to the target (c) divided by distance (d) of subject's eyes to the display (the tangent). The distance from fixation point to the target was calculated from screen coordinates (X, Y) obtained from each subsequent eye-tracker frames in period of saccade duration. Saccade record usually consisted 3-5 frames. Each subsequent distance between frame's coordinates was calculated as Euclidean Distance converted from pixels to centimeters. The distance between subject's eyes and the screen (d) was measured manually before each session. Average angular velocity expressed in degrees per second was calculated as the division, where amplitude (visual angle) obtained from saccade on-screen distance and distance between subject's eyes and the screen is the dividend and count of frames collected from the eye-tracker during period of duration is the divider, multiplied by eye-tracker frequency of 60 Hz. Peak angular velocity was counted as maximum value from velocity values, calculated and collected for every eye-tracked frame in the period of saccade duration. Pupil size was counted as the average of pupil size values from all frames collected by the eye tracker in the period of saccade duration.

Complete class of particular saccade contained following properties (Table 1). Properties: ID, Age, Sex describe subject, properties: Music, Mood describe session and properties: SccLat (Latency in ms), Dur (Duration in ms), Amp (Amplitude in deg), AvgVel (Average Velocity in deg/sec), AvgPupSize (Average Pupil Size in mm) describe saccade parameters.

Table 1. Saccade trial data row.

Id	Age	Sex	Music	Mood	Lat	Dur	Amp	Avg Vel	Peek Vel	Avg PupSize
id	age	M,F	-5,0,5	-5,-4,-3,-2,-1 0,1,2,3,4,5	lat	dur	amp	avg Vel	peek Vel	avg PupSize

Each of 3 sessions was conducted in 3 sequences of 10 saccade trials. In order to find regularities in calculated data, WEKA 3.6.13 was used for attribute selection, evaluation of means and classifications.

4 Results

We analyzed the results for attributes placed in the dataset except the attribute "Music". This experiment concerned mood influence on saccade parameters in different age groups and attribute "Music" was the contractual parameter defining session type. True feelings after listening to the musical piece, were indicated by subject himself in value of attribute Mood. Many times music did not have the desired effect and subject responded with contradictory value for "Mood', thus attribute "Music"was not taken into account during the dataset analysis.

First, we analyzed dataset contained Age property and saccade results and all subjects from both age groups. After attributes discretization, 2 different age groups of younger {<30 } and older adults {>60 } were selected for comparison of saccade parameters. Dataset assembled from both groups, was then filtered for attribute selection using WEKA Exhaustive Search and the Cfs Subset Evaluator [5], resulting in selection of attributes : Age, Latency, Amplitude and Pupil Size. Entire dataset contained 311 instances. Statistics are presented in Table 2.

Table 2. Comparison of mean values for age groups.

Age groups	Latency (ms)	Amplitude (deg)	Pupil Size (mm)
Younger adults (<30)	249.69 +/- 60.1 (SD)	5.12 +/- 0.8 (SD)	6.9 +/- 1.2 (SD)
Older adults (>60)	326.70 +/- 89.7 (SD)	5.05 +/- 0.7 (SD)	5.9 +/- 1.4 (SD)
Differences (%)	23.6	1.4	16,6
df	10	10	10
Standard error of difference	8.673	0.085	0.148
P	< 0.0001	0.4129	< 0.0001

Attributes Latency and Pupil Size have been found statistically significant. Size of human's pupil varies in range of 2-8 mm, so 1 mm difference is equal to the change of 16.6% in this scale. According to the results, saccades with average pupil size below 4.79 mm or saccades with latency over 265 ms might be assigned to the set of outputs of people over 60 years old.

Attribute Mood represents true feelings of subject after listening to the musical piece. Value of this attribute was indicated each time after music listening, by subject himself, in scale of -5 and 5, where -5 is the most relaxed and 5 the most energetic value of mood. There was 3 sessions types : without music (0), with energetic (5) and with relaxing music (-5). Mood value was given by subject himself at the end of each type of the session. Value was noted in questionnaire attached to each of session type records of particular subject. For some of the records, musical piece haven't influenced the subject, so mood value was not corresponding with session/music type (i.e. music -5, mood 3). It was also considered, that Mood might have different influence on different age groups, thus both youngest and oldest group of subjects were analysed separately. Values of attribute mood were discretized into 2 value groups representing negative (relaxed mood representing value range of {-5-0}) and positive (energetic mood representing value range of {0-5}) sides of mood value vector. In the next step data set has been divided into 2 separated ones containing data of younger and older groups of subjects. Then, both groups of subjects were filtered for attribute selection using WEKA Exhaustive Search and the Cfs Subset Evaluator [5]. For group of young adults reduction of attributes resulted in selection of Mood, Latency, Amplitude and Pupil Size and group of older adults had the same attribute selection. Dataset of younger adults contained 229 instances and dataset of older adults contained 145. Statistics are presented in tables 3, 4.

Table 3. Means of attribute Mood in age group of younger adults {<30}.

Mood groups	Latency	Amplitude	Avg Velocity	Pupil Size
-5-0	251.5 ms +/- 50.4 (SD)	5.0 deg +/- 0.6 (SD)	95.3 deg/sec +/- 16.8 (SD)	7.3 mm +/- 1.3 (SD)
0-5	248.9 ms +/- 64.8 (SD)	5.2 deg +/- 0.8 (SD)	98.3 deg/sec +/- 18.0 (SD)	7.0 mm +/- 1.2 (SD)
df	226	226	226	
Standard error of difference	7.689	0.094	2.306	0.166
P	0.7356	0.0338	0.1946	0.0715

Table 4. Means of attribute Mood in age group of older adults {>60 }.

Mood groups	Latency	Amplitude	Avg Velocity	Pupil Size
-5-0	316.4 ms +/- 84 (SD)	5.2 deg +/- 0.6 (SD)	100.4 deg/sec +/- 12.8 (SD)	6.2 mm +/- 1.4 (SD)
0-5	326.5 ms +/- 77 (SD)	4.8 deg +/- 0.6 (SD)	93.4052 +/- 16.3 (SD)	5.6 mm +/- 1.3 (SD)
df	142	142	142	
Standard error of difference	13.429	0.100	2.442	0.225
P	0.4532	0.0001	0.0048	0.0086

According to the results attribute Latency has been found statistically insignificant. Also significant difference was observed in the Amplitude among younger group and in the Amplitude, the Average Velocity and the Pupil Size among older group. Interestingly, in group of older adults pupils were 0.5 mm larger for sessions with relaxed mood, while in group of younger adults pupil size seems to be static and not fragile for mood changes. 0.6 mm is equal to the change by 13% in pupil's size scale defined by possible range of 2-8 mm. According to this, saccades performed by subjects over age 60, with respectively different average pupil size, could be assigned to the set of results for one of side of the mood vector. It seems that in the elderly, pupil size and latency plays more important role in distribution of saccade parameters depending on mood, perhaps because they present with abnormalities connected to age or disease. Obtained results proves that Latency and Pupil Size, along with Amplitude and Average Velocity could be found as differentiators between saccades made by people in different age and moods. Thus theoretically, age and mood of particular subject could be predicted from parameters of saccades. For this purpose, accuracy of model presented in the ”Results” section has been tested against collected data with different types of classifiers: Random Forest (RF), Multilayer Perceptron (MLP), Naive Bayes (NB) and Support Vector Machine (SVM), in same WEKA's procedure of cross-validation of 10 folds [5]. Algorithm used in WEKA divides dataset into 10 folds and perform tests and train procedure for each fold with the remaining 9, giving in the result the average of 10 evaluations [5]. From classifiers enumerated above, two classifiers - RF and MLP - showed highest and almost equal accuracy.

For classification of Age groups, best results has been obtained for dataset containing all attributes collected during the experiment and with attribute Age discretized into 2 bins, matching old and young adults groups and also with attribute Mood discretized into 10 bins, matching granular values of the mood vector. For such dataset, both MLP and RF showed the same accuracy of prediction of 91.4% (correctly classified instances). In case of the Mood groups, best result also has been obtained for dataset containing all attributes, with attribute Age discretized into 44 bins (23 was the youngest and 67 was the oldest subject) and also with attribute Mood discretized into 2 bins, representing 2 sides of the mood vector. For MLP, the percentage of correctly classified instances was 96.6%, while RF performed slightly better with 97% correctly classified instances.

5 Discussion And Conclusions

The purpose of this experiment was to show that depending on the age, emotions affect saccade parameters (thus, the eye movement) in different ways and that these parameters can be used to classify subject to one of the defined group of age and mood. We also wanted to describe main differences between groups in our results. When comparing means of people under 30 with people over 60, significant difference can be noticed in ranges of values for attributes Latency and Average Pupil Size (Table 2). According to the results, mean latency of older people is ∼23% (∼77 ms) slower than among youngest group.The results are also different in pupil size. According to the results, average pupil size among older people is ∼17% (1 mm) smaller, comparing to age group below 30. Both attributes has been found statistically significant. This findings and size of the difference seems to be consistent with results obtained by researchers mentioned earlier in this article, stating that only those two parameters are sensible for age related changes [11, 12, 17].

According to the results, latency seems to be the most sensitive to the age of all saccade parameters and variability of latencies is an interesting phenomenon of which mechanics has been described at least by two theoretical models: LATER (Linear Approach To Threshold With Ergodic Rate) [7] and SAT (SpeedAccuracy Tradeoff) [14], [16], [1].

Mechanics presented by both models are based on theory of accumulation of sensory evidences. So, according to our results one can hypothesize, that older people may need more time to accumulate enough evidences to commit decision with appropriate accuracy. This response time is defined by threshold of sensory input which might be different in older people, due to greater length of sampling, computation or communication process between brain areas. Those differences may have source in changes in brain due to age or neurodegeneration, but it may also come from the developing disease. Latency parameter of saccades seems to be most sensitive to these changes and shows how different brain processing is among group of older people.

When comparing influence of music expressed in attribute mood, we can see differences in attributes significance between both age groups. Among people between 20-30 years old (Table 3) actually only attribute Amplitude can be considered as marginal difference between relaxation (lower values) and arousal (higher values). Among older people, attributes significance looks slightly different. We can see that attributes Amplitude, Average Velocity and Pupil Size can be considered statistically significant (Table 4). Means of pupil size in group of people over 60 are different between moods by $\sim$13%. This difference also occurs in group of people below 30, however is not significant. This result partially follows findings made by Gingras, Marin, Puig-Waldmller and Fitch in their research on young people pupillary responses to the music [2]. However in case of this experiment, music was played before, not during measurement sessions to avoid interaction with ANS. So strong, post-music listening pupillary response found only in older people seems to be an interesting output for further investigations.

In case of Amplitude and Average Velocity, in group of people over 60 we can see much stronger significance, when comparing to group of young adults. Interestingly, values of both parameters are lower for energetic mood. This phenomenon is not following the widespread assumption, stating that arousal increases saccade amplitude and velocity. However there are several factors that could decrease saccade performance in older adults despite the state of arousal. It could be level of fatigue, decreased task difficulty due to retrain or decreased motivation, reward or effort, as sessions with energetic music was performed always at the end of the experiment [13].

The experiment showed that same task repeated in different emotional conditions by people in different age brings different outputs. Our results showed that in case of saccades, it appears to be possible to track down differences and classify subjects to defined ranges of age or mood with satisfying prediction ratio. This proves the sense of experiments involving the classification of the subject based on oculometric measurements.

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