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Influence of Mood on Saccadic Eye Movement Parameters in Different Age Groups

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Abstract

There are many evidences about unique emotions evoked by music in different individuals and that, the saccadic eye movements (saccades) and pupil size are sensitive to different emotions. The experiment presented in this article concerns both issues, as we investigated possible changes in parameters of saccades, caused by emotions induced by music listening. It was assumed, that found correlations will help to determine subject's age and mood dependently on recorded saccade parameters. The purpose of this experiment was to find ability to distinguish and classify saccade parameters to one of defined groups of age (young/old) or mood (energetic/relaxed) induced by music.

We have measured saccades of two groups of 6 subjects in age below 30 and over 60, during musical sessions with energetic and relaxing music. Collected data were analyzed in search of possible correlations between characteristics of respondents and saccade parameters, using combination of different types of filters and classifiers from WEKA. Classifications showed statistical changes between age groups, in the latency (23.6% of difference) and in the pupil's size (16, 6% of difference), both found extremely significant (P>0.0001). In case of Mood, results showed changes in the group of younger adults, in the latency (P=0.4532) and very significant for the amplitude (P=0.0001) and for the average velocity (P=0.0048). The best classification results were obtained for Age and Mood groups. Prediction of age group showed the accuracy of 91.4%. In case of Mood groups, obtained percentage of correctly classified instances was between 96.6 and 97%. For both types of groups, best predictions were obtained by Random Forest and Multilayer Perceptron. The results of classifications allowed to build the confusion matrix and decision trees based on values of saccades parameters and data of subjects. It showed differences in saccade processing between particular groups. Article tries to explain main differences in obtained results by SAT and LATER models, exemplifying the computational nature of human brain processing.

The comparison of predictions made on the basis of the obtained results, showed acceptable statistics for examined subjects, which may suggest further researches at the intersection of machine learning, human age, mood, and eye moves. The results of this experiment suggest usefulness of the Eye Tracking and Eye Movement parameters classifications in machine learning driven detection of human features.

Keywords: Eye moves; Saccades; Eye tracking; Eye move computations; Brain computations; Human features; Emotions; Moods; Age; Machine detection; Classification

Introduction

Music

Music has a fundamental effect on humans. It makes individual want to move, gives experience of pleasure and delight that is highly specific to cultural background and personal preferences. It was shown that during motor activity, music optimizes arousal, facilitates task-relevant imagery and improves performance in simple and repetitive motor tasks [1], like saccadic eye movements.

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." A number of studies have reported that listening to relaxing music can lead to decreased heart rate, respiration rate, and blood pressure" [2]. Few studies reported spontaneous entrainment of blood pressure and respiration rate to musical tempo. It was assumed that such changes may be an important factor in case of listening to energetic music which usually has a faster rhythm". Humans interact with music, both consciously and unconsciously, at behavioral, emotional, and physiological levels" [2]. Those interactions certainly affect motor system, thus also have effect on saccadic eye movements. 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.

Saccades

"Saccades are rapid, ballistic movements of the eyes that abruptly change the point of fixation" [3]. They are very varied in terms of visual angle, from small saccades made when we read, to longer movements when we look around ourselves". Saccades can be elicited voluntarily, but occur reflexively whenever the eyes are open, even when fixated on a target" [3]. Human eyes make saccades when watching available field of view, fixing on interesting elements of the surroundings. The cause of this phenomenon has its base in the method of operation of the part of the eye capable of extracting detailed visual information - the fovea". The fovea receives input from only a small portion of the visual field. Thus, in order to view a complex scene, the fovea must often be moved to new fixation locations" [4].

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The speed of movement during each saccade cannot be controlled - the eyes move as fast as they are able, reaching the highest speed at around 15 [5]. Saccades play an important role in perceptual processes, through which brain is able to construct representations of surroundings [6] and may also reflect movements of visual attention" [5]. Saccade are also used while reading, then its function is to bring a new chunk of text into vision for semantic and syntactic recognition [6] and when brain rapidly refocuses foveal vision and visual attention toward changes in the visual field or locations of interest, resulting in change of eye's fixation position [4]. Saccades are very common in the functioning of the oculomotor system, occurs up to 173,000 times per day [7]. They are not always precise, sometimes undershoot or overshoot the target [5]. The relationship between its distance and duration is usually quite similar among different individuals, however, they are slower than normal when present in certain pathologies [5].

Saccade generation and triggering is controlled by an extensive cortical and subcortical network, with cortical-midbrain pathways differing for the mode of oculomotor response required to acquire a visual or nonvisual target. The network for control of visually guided and predictive saccades encompasses the occipital cortex, posterior parietal cortex, posterior eye fields, prefrontal cortex and frontal eye fields (which then project to the superior colliculi and reticular formation). Positron emission tomography imaging has shown increased activation in the frontal eye fields, supplementary motor area, thalamus, putamen, superior parietal lobe, and primary visual cortex during execution of the antisaccade task compared to the prosaccade task" [8]. Thus, saccade generation and triggering seem to be very sensitive to any neurodegenerative changes correlated to age or disease.

Age

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 [8]. Older adults have longer latencies in a variety of motor tasks (i.e. aimed hand movements) [4]. The magnitude of the slowing varies considerably between studies, i.e. from 20 ms to 100 ms, however there is general agreement that older participants show longer latencies, when directly compared to younger participants [8]. According to Abrams, Meyer and Kornblum" both eye and limb movements are controlled through stochastic force and time parameters that govern movement kinematics" [5]. Such view promotes a "unified conceptual framework for understanding a wide range of motor behavior" which defines movement of any part of the body including eyes, as a result of pulse force applied for a necessary amount of time by "opposing groups of agonist and antagonist muscles" [5]. 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. [4]. It seems to be true, as specific task may also be affected by other age-related factors. In case of saccade trials there is evidence indicating that as people become older, inhibition of inappropriate response becomes less effective, as well as suppression of irrelevant information. It seems that younger adult is more susceptible to the priming effect occurring when both stimuluses shares certain features and therefore the distractor influences the response [4]. However, it also seems that older adults produce saccadic eye movements in fundamentally the same way as younger adults and age-related deficits in inhibition occurs in tasks in which the response relays on recognition of object properties, but not in tasks where the response is based just on spatial location. It may suggest that mechanism which itself triggers and controls the saccade may not be degraded with progressing age [4].

In terms of pupil size, few researches state 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 [9], so the average pupil size of 20-30 years adult is ~ 6.9-6.5 mm, while pupil size of 60-70 years adult is ~ 5.1-4.8 mm [10].

Emotions

There is still uncertainty as to whether or not the older age affects the performance of saccades. In addition, emotional states - depression or anxiety connected with particular mood, both of which are common in older people and increasing with age, may also interact and impair or alter saccadic task performance [8]. Negative relationship between saccadic task latency and depression has been indicated as well as a positive relationship between saccade error rate and trait anxiety. Mood measurements did not indicate any other significant relations with oculomotor dependent variables [8]. This statement is the subject to ascertainment by this study.

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. However, an interaction between arousal and liking for the excerpts suggests, that pupillary responses modulate less strongly by arousal when the excerpts were particularly liked. An analogical interaction was observed between tension and liking, additionally, males exhibit larger dilations than females. Overall, findings also suggest a complex interplay between different influences on pupillary responses to the music [11].

Emotions induced by music, may also directly influence execution of the saccade. Matthias J. Wieser, Paul Pauli, Andreas Mhlberger have shown that in anxiety, some of individuals have a problem with efficiency of attentional system focused on execution of particular task. They claim that emotions can change the balance between two attentional systems: the objective-oriented (influenced by current targets) and the stimulus-driven (influenced by performance of environmental input). It is assumed that these two systems are interacting during performing a task and anxiety increases the influence of stimulus-driven system [12]. Such an imbalance could reduce inhibitory control of attention, which could be beneficial in terms of decreased length of saccade latency, because of reduced fixation inhibition. However, it also seems that this emotional effect should be rarely encountered in older adults, as they are not affected by the explicit cue to focus on their emotions [13].

Research purposes

The experiment described in this article, was conducted to determine possibilities of saccadic parameters prediction from age and mood measurements, in context of effects made by emotions induced by music listening - which is not well studied and understood yet. Additional purpose of this experiment was to show the impact of the music on this type of eye movement. Saccades of subjects were measured and recorded during different sessions: without music and when measurements were preceded by listening of stimulating or relaxing music.

Data collected from different types of sessions were analysed in order to find correlations between parameters describing saccades and properties describing age and subject's mood. It was assumed, that detection of possible correlations may help in better understanding of relationships between induced emotional moods and changes, that may arise due to age and oculomotor control described by saccade parameters.

General assumption of this experiment was to determine confusion matrix using data filtering and classification, that allows to predict assignment of saccade record, to one of defined groups of age and mood values. From various series of tested algorithms have been selected, those, whose results gave the most significant relationships in the statistics. Tree visualizations made over built model allowed to see distribution of calculated parameters and attributes of subjects, indicating variants of oculomotor processing depending on age and mood. Built model was also tested against the effectiveness of the predictions that could be used in machine detection of human features like attributes (age) and states (mood) based on analysis of eye moves. The accuracy of predictions was tested with learning models of decision trees (Random Forest), artificial neural networks (MLP) and probabilistic classifiers of Naive Bayes and Support Vector Machine.

In addition to human feature detections, analysis of saccadic responses to visual cognitive tasks may bring some understanding of the mechanisms of brain processing derived from the results. Thus, eye movement measures have proved also to be a valuable tool for evaluation of neurological impairment in a range of neurodegenerative disorders.

Experiment details and methodology

Subjects

12 subjects, different gender and aged 23 to 67 divided into two groups of young (six subjects in age between 23-30) and old adults (six subjects in age between 60-67). 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 - calming and also stimulating. It can be said, that only people who declared emotional sensitivity to music took part in the experiment.

Apparatus and procedure

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 ThinkVision 6636 15" LCD square display (1024 × 768 px) from distance of 60 cm in 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 it was the primary position of the gaze for each saccade trial. Subject had to keep eyes on the fixation point for randomly selected time period, between 1000 and 2000 milliseconds to initiate saccade measurement process. Eye movements were measured in response to fixation and target points switched sequentially on and off. The target always appeared in the same vertical location as location of fixation point and has exactly same shape of the ellipse.

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 points shortly before the appearance of a 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 [1,14], 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 [8]. The Gap model shows latencies adjusted by this phenomenon, thus shows reduced differences in response time between both age groups.

Subjects were asked to perform saccades from fixation point to the 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, as subject never knew exactly when another trial starts.

Musical pieces selection

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 influence every participant. Musical piece was listened to on closed headphones before sessions of Energetic and Relaxed mood. In data of each saccade record, energetic music was described as number 5 and relaxing music as -5. As in case of "Gap Effect" model selection, it has been determined that the respondents will choose music they know and like, as pupillary responses should modulate less strongly when track is particularly liked [11], thus should reduce differences between different mood groups.

Sessions

Experiment was conducted in different 3 sessions of saccades recording, for "music off", energetic and then 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 saccade measurements to avoid interactions with Autonomic Nervous System which can lead to changes in heart rate, respiration rate, electrodermal activity, blood pressure and pupillary response which could affect oculomotor system, thus also the results of saccade measurements [2].

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 frame of mind, -5 is the most calm and 5 is the most excited. Each of sessions contained 3 sequences of 10 saccade tries and subject was recorded during all 3 session types. Each session lasted about 15 minutes. Subject himself decided when to start another sequence of saccade measurement, so he could rest between them. Subject also himself decided, when to stop listening to music. It was said, that it was supposed to be at a moment when he felt the music had a profound effect on him.

All of records were validated against straight-aimed move from fixation to the target (programmatically and confirmed manually). Any saccade records which hadn't passed for typical in this measurement criteria (multiple velocity peaks, position shifts) were removed from the original dataset (around 10%). Experiment sessions were conducted in similar, artificial lighting conditions. Subject didn't left the room between sessions, staying in place during whole experiment.

Eye-movement recording, calculations and analysis

The output from the eye-tracker contains raw data of eye properties and coordinates measured in frequency of 60 Hz. Data log of each saccade was analyzed by application which calculated saccades latency, duration, amplitude, average velocity, peak velocity and average pupil size. In order to find regularities in calculated data, WEKA 3.6.13 was used for attribute selection, evaluation of means and confusion matrices.

Latency

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 this record. Additionally, application detected and recorded the moment in time when subject's gaze focusses left fixation point, which served as additional information used in saccade start time validation.

Duration

Duration of the saccade was determined as the period, when gaze velocity (deg/sec) was over velocity threshold, calculated for the entire record including the latency period. Additionally, application stopped saccade recording 1 frame after the moment, when subject's gaze reached the target. Both latency and duration were calculated in milliseconds. Velocity threshold used for saccade start and end point detection was calculated from all subsequent frames of the record including latency period by dividing the maximum speed (V max) by the average speed (V avg), thus: $V_{threshold}=V_{max} \div V_{avg}$.

Amplitude

In order to know the amplitude of saccade, the visual angle must be evaluated. The visual angle of the image on the retina can be calculated by measuring the angle subtended by the object outside of the eye. This is true because q=q' (Figure 1). 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).

We can define visual angle as $\tan\theta = (|ba| \div d)$ where $\theta_1 = \arctan(|ba| \div d)$ and $\theta_1 = \theta_2 \therefore \theta = 2 \times \theta_1$ [10]. The distance from fixation point to the target was calculated from screen coordinates (X, Y) obtained from each subsequent frame (p1, p2) in period determined by saccade duration. Saccade record usually consisted 3-5 frames. Each subsequent distance between frame's coordinates (D) was calculated as Euclidean Distance converted from pixels to centimeters, as is: $|ba| = (\{D_1 + D_2 ... + D_n\} \div 2)$. The saccade on-screen distance was calculated as a sum of those distances divided by half, giving the distance between point 'b' and 'a' from Figure 1 which is: . The distance between subject's eyes and the screen (d) was measured manually before each session.

Average angular velocity

Average angular velocity (Ω) expressed in degrees per second was calculated as the division, where amplitude (Θ visual angle) obtained from saccade on-screen distance and distance between subject's eyes and the screen, is dividend and count of frames (ΣF) collected from the eye-tracker during period of duration is the divider, multiplied by eye-tracker frequency (Tf) of 60 Hz, as follows: $\Omega = (\theta \div \Sigma F) \times Tf$.

Peak angular velocity

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

Pupil size was counted as the average of pupil size values, for all frames collected from the eye tracker in the period of saccade duration (when velocity was over calculated threshold).

The dataset

Each session was conducted in 3 sequences of 10 saccade trials. Complete data row of particular saccade contained following properties (Table 1).

Where properties: ID, Age, Sex describes subject, properties Music, Mood describes 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) describes saccade parameters, calculated from tracker outputs for each saccade record session. The saccade result class might be described as a set of properties: Scc = {SccLat, SccDur, SccAmp, SccAvgVel, SccPeekVel, SaccAvgPupSize}.

Results

Attribute music

This experiment concerned mood influence on saccade parameters in different age groups. 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 it happend, that music hasn't had the desired effect and subject responded with contradictory value for "Mood", thus attribute "Music"was not taken into account during the dataset analysis.

Attribute age

Dataset contained Age property and saccade results from subjects in age between 23 and 67 years old. After attribute discretization, 2 most extreme age groups of younger {-inf.-30} and older adults {60-inf.} were selected for comparison of saccade parameters. Dataset

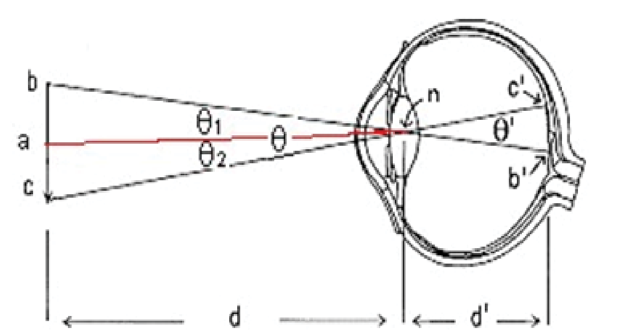

Figure 1: Visual angles for an object.

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

Table 1: Saccade trial data row.

assembled from both groups, was filtered for attribute selection using Exhaustive Search and the Cfs Subset Evaluator, resulting in selection of attributes: Age, Latency, Amplitude and Pupil Size. In the next step, dataset containing those attributes was classified using Naive Bayes with cross validation of 10 folds for evaluation of saccade parameters mean values in context of age groups. Dataset contained 311 instances, 79,4% of them was correctly classified. Results of this classification are presented in Table 2.

In the results of Naive Bayes classification, only 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. In the next step, dataset contained attributes Latency and Pupil Size has been classified by Decision Tree J48 with cross validation of 10 folds in context of age groups. Classification of 78.7% correctly classified instances, resulted in decision matrix that can be represented by graph below (Figure 2).

We can see that 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. The decision tree based on values of saccade parameters, regards concept of confusion matrix which allows to assign a saccade record to defined groups of age.

Attribute mood

Attribute Mood represents true feelings of subject after listening to the musical piece. Value 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 were 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 hasn't influenced the subject, so mood value wasn't 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 {-inf.-0}) and positive (energetic mood representing value range of {0-inf.}) sides of mood value vector. In the next step data set has been divided into 2 separated datasets containing data of younger and older groups of subjects. Then, both groups of subjects were filtered for attribute selection using Exhaustive Search and the Cfs Subset Evaluator. For group of young adult's reduction of attributes resulted in selection of Mood, Latency, Amplitude and Pupil Size and group of older adults had the same attribute selection. In the next step, both datasets containing selected attributes were classified with Naive Bayes with cross validation of 10 folds, for evaluation of attribute mean values in context of mood groups. Dataset of younger adults contained 229 instances, with classification ratio of 48%, and dataset of older adults contained 145 instances, with classification ratio of 73%. Results of this classification are presented in Tables 3 and 4.

In the results of Naive Bayes classification, attribute Latency has been found statistically insignificant. Significant difference observed in results was in Amplitude for younger adults and in Amplitude, Average Velocity and Pupil Size for 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. In the next step, the J48 algorithm has been used to generate decision trees of both datasets with cross validation of 10 folds in context of Mood value groups {-inf.-0} and {0-inf.}. For age group of younger adults, it was 59.7% correctly classified of 229 instances and for older adults it was 69.6% of 145. Obtained decision trees for both age groups are represented by Figure 3 and 4.

Figure 3 looks similar to right trunk of the tree of older adults' group (Figure 4). It contains the same attributes and starts with the same root node the Amplitude. However, decision tree of older people contains additional trunk, not present in the tree of young group, showing the difference in processing, in various emotional states, between the two groups. It seems that in the elderly, pupil size and latency play more important role in distribution of saccade parameters depending on mood, perhaps because they present with abnormalities connected to age or disease. We can see that one branch of the left trunk of tree of older adults presents enormous pupils' dilations in state

Age groups	Latency (ms)	Amplitude (deg)	Pupil Size (mm)
Younger adults	249.69	5.12	6.9
(-inf.-29)	± 60.1 (SD)	± 0.8 (SD)	± 1.2 (SD)
Older adults	326.7	5.05	5.9
(60-inf.)	± 89.7 (SD)	± 0.7 (SD)	± 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 (xtrm sig)	0.4129 (not sig)	>0.0001 (xtrm sig)

Table 2: Comparison of mean values for age groups.

Mood groups	Latency	Amplitude	Avg Velocity	Pupil Size
-inf.-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-inf.	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	0.1	2.442	0.225
P (not sig)	0.4532 (xtrm sig)	0.0001 (v sig)	0.0048 (v sig)	0.0086

Table 3: Means of attribute Mood in age group of younger adults {-inf.-30}.

Mood groups	Latency	Amplitude	Avg Velocity	Pupil Size
-inf.-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-inf.	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	0.1	2.442	0.225
P (not sig)	0.4532 (xtrm sig)	0.0001 (v sig)	0.0048 (v sig)	0.0086

Table 4: Means of attribute mood in age group of older adults {60-inf.}.

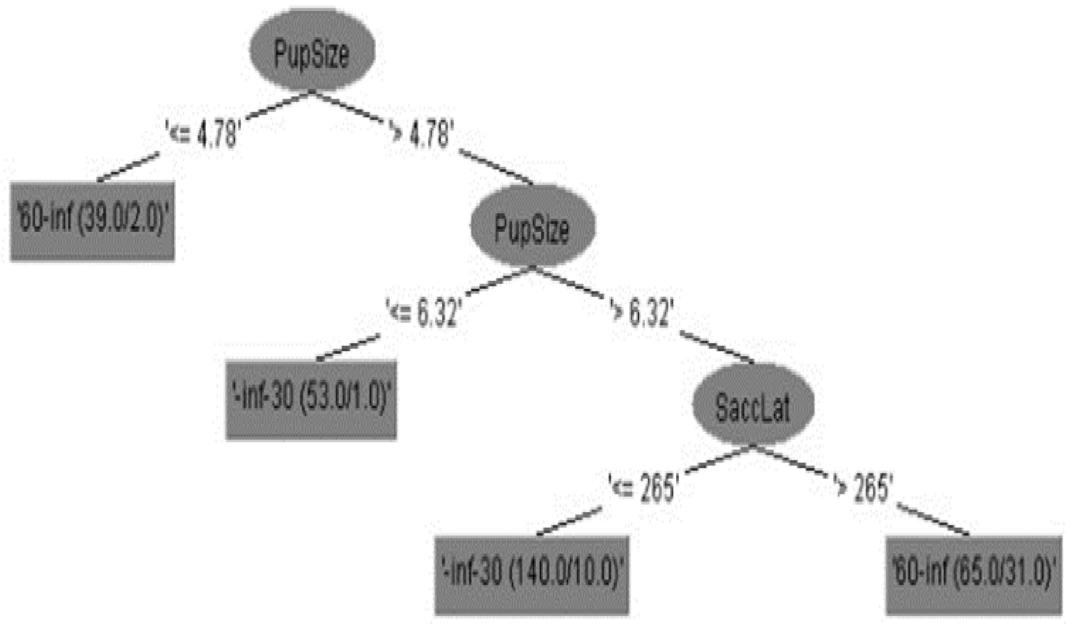

Figure 2: Decision Tree for attribute Age.

of relaxation, while the other one, enormous long latencies in state of arousal (Figure 4). Indeed, such derogations may indicate symptoms of pathology in some subjects, connected to neurological changes in the nervous system. As the explanation for long response time might be simple - general and far-reaching slowness due to an overall slowing of information processing in particular subjects, the explanation for enormous pupil dilations seems to be a complex interplay between different influences, starting from changes in accommodation and emotional processing.

Age and mood prediction

Results of this experiment proves that Latency and Pupil Size, along with Amplitude and Average Velocity can be recognized as marginal differentiators between saccades made by people in different age and different 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 procedure of cross-validation of 10 folds. From enumerated above, two classifiers - RF and MLP - showed highest and almost equal accuracy.

For classification of Age groups, best results have 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.

Results and Discussion

When comparing means obtained from results of young people under 30 with people over 60, significant difference can be noticed in ranges of values for 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. Results also differs in average 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 have been found statistically extremely significant. This finding seems to be consistent with results obtained by researchers mentioned earlier in this article, stating that only those two parameters are sensible for age

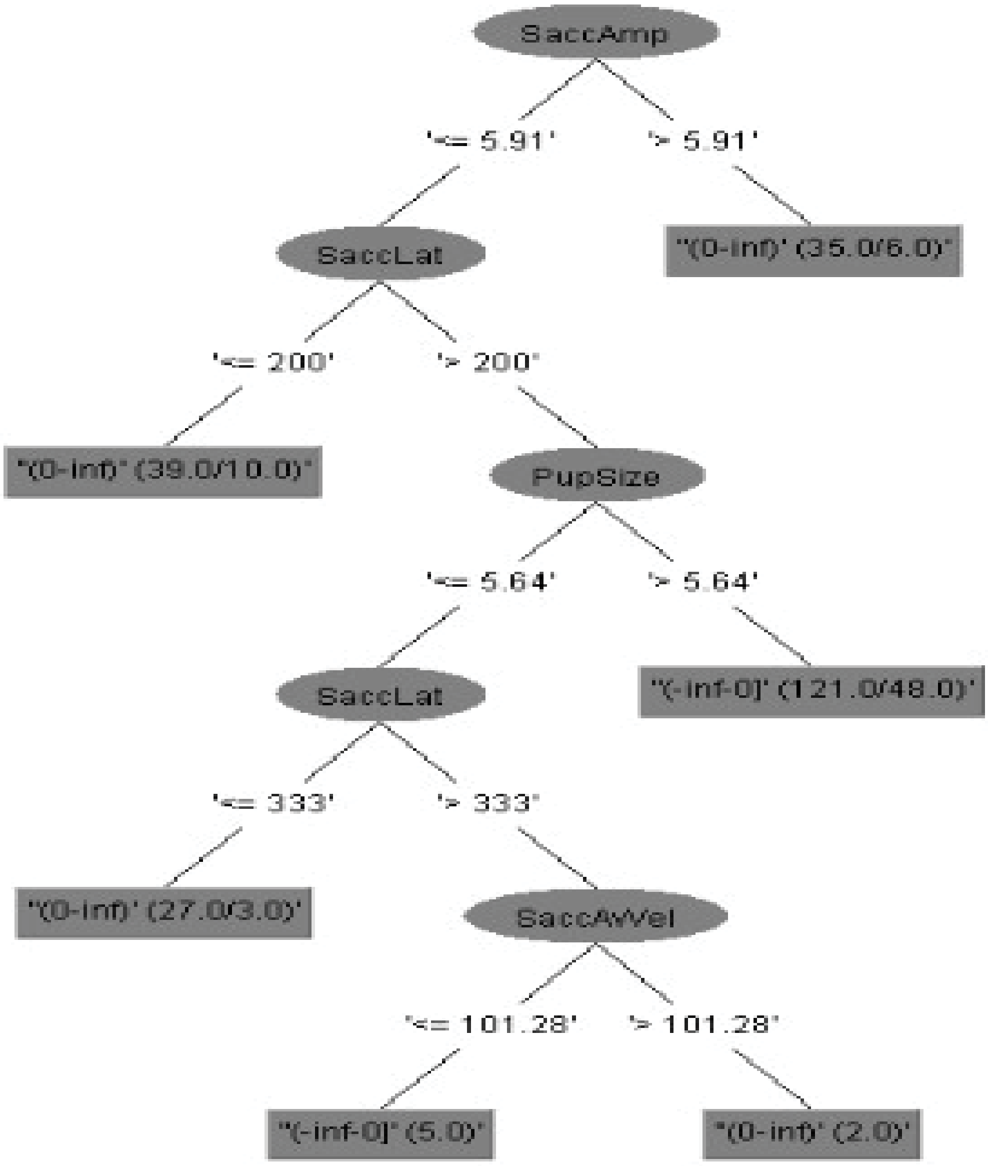

Figure 3: Decision Tree for attribute Mood in age group {-inf.-30}.

related changes [1,7,15]. Also, size of the difference for both parameters corresponds with the results from other studies.

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) and SAT (speed accuracy tradeoff). As it was noted previously that saccadic and limbic latencies share similar properties including latency to auditory or visual stimuli, thus, both can be modeled similarly by linear distributions. "If reciprocal latencies are plotted cumulatively (a reciprobit plot) then a straight line is obtained" [16]. Such a distribution can be explained by the LATER model (Figure 5). The rise of the decision signal to threshold in LATER model is thought to be an accumulation of sensory "evidence" for a hypothesis, and this accumulation occurs in a linear fashion. "Once enough evidence for a certain hypothesis is accumulated, signified by the decision signal reaching its threshold, then this hypothesis is accepted and a decision to respond is made" [16]. From many possible choices, the final choice comes out of a number of options and occurs when the decision signal for particular choice reaches threshold before the decision signals representing the other options. A simple saccade task with a fixation point and target performed by subjects in this experiment, can be modeled by LATER, if peek of stimulus represents disappearance of fixation point and appearance of the target and decision signal which accumulates information about the decision, based on supplied information and rises toward threshold in a linear fashion, triggering a response (the eye movement) when it reaches threshold [16].

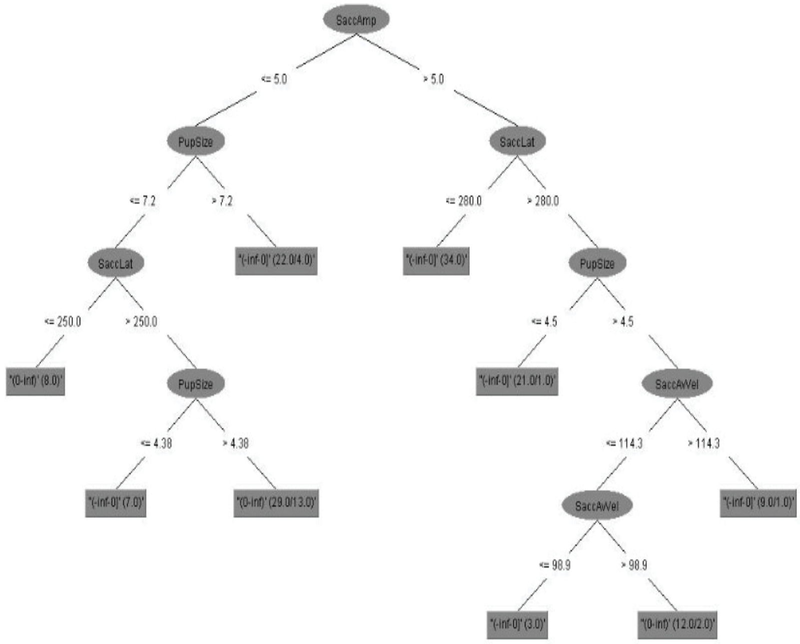

Figure 4: Decision Tree for attribute Mood in age group {60-inf.}.

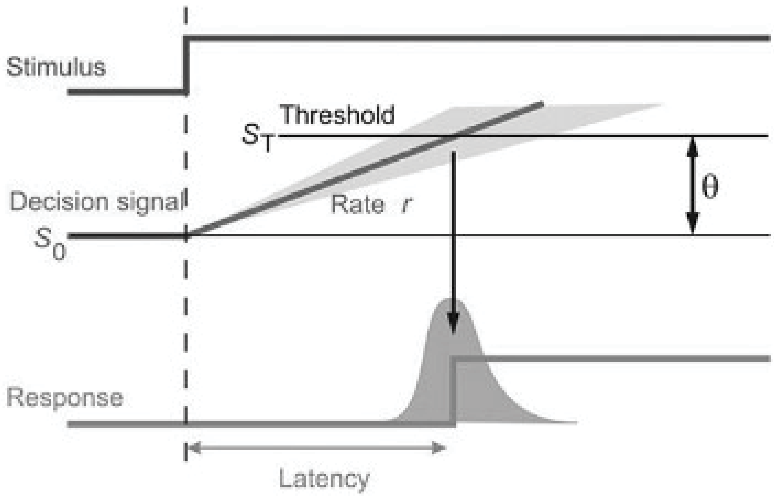

Figure 5: The LATER model (Noorani, 2014).

This decision process represented by length of S_O and S_t certainly includes communication between different parts of brain, view field analysis and final computation of muscle tension resulting in eyeball rotation.

The SAT model theory (Figure 6) seems to be an important amplification of the LATER model. The SAT model also assumes, that choice process involves a series of "implicit responses" arising from the presentation of a sensory signal and seems to be closely related to, what we might now call "perceptual accumulation" [16]. During a choice trial, observers obtain successive samples of implicit responses and some counting mechanism keeps track of the number of consecutive runs favoring either one of potential actions [17]. An updated posterior probability can be computed by simply sampling information sequentially. The problem is that information is costly-each sample takes some quanta of time and effort; Therefore, it is in one's best interest to sample as little as possible to reach some specified compromise between confidence and time spent sampling" [17].

"The SAT arises due to the inherent contradiction between response speed and decision accuracy. Faster responses entail less accumulated evidence, and hence less informed decisions. Observers set a decision criterion - an amount of evidence required to commit to a choice - based on current task demands and internal goals" [16].

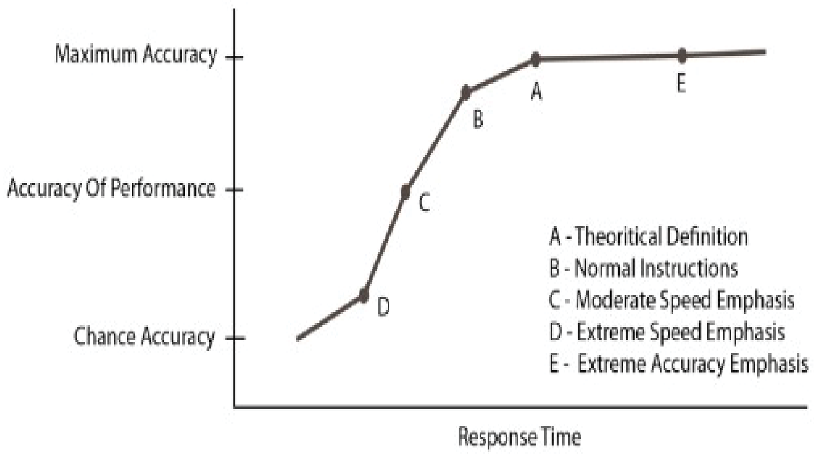

Figure 6: Idealized speed-accuracy operating characteristics.

If the mechanics presented by both models is true, according to the 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 older people [18,19].

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 (Table 3) actually only attribute Amplitude can be considered as marginal differentiator 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, when we want to distinguish saccades performed in these different moods (Table 4). Means of pupil size in group of people over 60 are different between moods by ~13%. It also occurs in group of people below 30, however difference in this group is not that quite statistically 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 [11]. However, in case of this experiment, music was played before, not during measurement sessions to avoid interaction with Autonomic Nervous System. 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 statistical importance, 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 [14], as sessions with energetic music was performed always at the end of the experiment.

Conclusions

The experiment showed that same task repeated in different emotional conditions by people in different age brings different results. In case of saccades, it appears to be possible to track down differences and represent it as confusion matrixes and decision trees. Based on statistical significance, those differences can be used for creating predictions for recognizing and assigning particular saccade record into defined group of values. It is hoped that in future, methods presented in this article will not only be useful in determining the age or the emotional state basing on eye movements parameters, but also will help to determine the deviation from the norm, announcing neurodegenerative changes in the human brain encountered in such conditions as Parkinson's Disease.

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