Final Report

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Team Tau

Investigating the effects of altered colour perception on mood

Joost van Amersfoort

Sanne Balvert

Simon Jonas Hadlich

Matthias Härter

Felicia Liu

“Fancy coloured glasses!”

Introduction and Literature Review

There exists a large body of anecdotal knowledge linking particular colours to specific psychological moods, red being described as an “active” or “aggressive” colour and on the other hand blue as being calming, for example. This mood-altering influence has been investigated in studies from various fields. In a range of experiments, researchers have examined the influence of room colour on mood and work performance (Küller et al. 2006; Kwallek & Lewis 1990; Ainsworth et al. 1993; Hamid & Newport 1989). An investigation of the effect of colours on brain activity using EEGs comes from Yoto et al. (2007).

Kwallek and Lewis (1990) found that after performing a proof-reading task, subjects in a red office environment would report more tension and make more errors than those in a white room. However, Ainsworth et al. (1993), in a similar setting involving typing tasks and a questionnaire assessing anxiety, arousal, and depression, did not find a significant effect. Apart from workplace experiments, a study by Hamid and Newport (1989) on physical strength and mood in children found that preschool children demonstrated "physical strength and high positive mood" in a pink-coloured room, while the reverse was true in a blue environment. Furthermore, in a related study on laboratory mice, Glen and Sherwin (2003) found that mice preferred white over red cages, with black and green ones in between. The authors report a significant effect of cage colour on body weight and consumption behaviour, as well as some evidence resulting from maze experiments indicating greater anxiety in mice with red home cages.

Yoto et al. (2007) studied the "physiological effects of color in terms of blood pressure and the results of electroencephalogram (EEG) as subjects looked at the sheets of paper of various colors". They found that red, green, and blue showed "distinctly different effects on the mean power of the alpha band, theta band, and on the total power in the theta-beta EEG bandwidth and alpha attenuation coefficient (AAC)", as well as in the subjective evaluation via a questionnaire. The authors report that in contradiction to participants' subjective evaluation, "blue elicited stronger arousal than did red as expressed by the results of AAC and the mean power of the alpha band", which they argue might be caused by the "biological activating effect" of bluish light. Furthermore, when participants looked at red paper, "the powers of the alpha band, and the theta band, and the total power of the theta-beta bandwidth as measured by EEG showed larger values". According to the authors, this might indicate that red elicited an anxiety state causing a higher level of brain activity. As they wrote, "[r]ed paper's effect to activate the central cortical region with regard to perception and attention was considerably more distinguishable than was the biological activating effect of bluish light in our study."

To conclude, research mostly from ergonomic studies suggests a mood-altering effect of short- and medium-term exposure to colours. Colours with a high wavelength, such as red, are reported to possibly increase tension, anxiety, as well as demonstration of physical strength and positive mood. Both humans and laboratory mice prefer a white environment, which is correlated with lower error rates in humans, and lower anxiety in mice. Evidence from an EEG study suggests that exposure to red colour elicits an anxiety state which causes increased brain activity. However, to our knowledge there are no studies concerned with the effect of long-term (more than an hour) exposure to a colour, in particular when colour vision is completely altered, on psychological mood and brain activity. Our study will address this research gap.

Design of the experiment

As described in the previous sections, this experiment will try to find an answer to our research question. This research aims to obtain knowledge about the influence of direct colour perception on mood, perceived by EEG (electroencephalongram).

The EEG measuring devices that will be used are the Emotive EPOC headsets available in the Beta Lab. It consists of sixteen sensors, of which two are used as references to measure the base resistance of the subject’s skin and skull. This measured base resistance is used to correct the raw data and to filter out influences from the environment. There are also two dummy “sensors” that assist the experiment conductor in placing the sensor on the subject.

An EEG device measures the electrical potential on the scalp in the range of 10 to 100 µV, of groups of millions of neurons. If a neuron fires, an electric current is running. Such measurements are very precise in time, and less in space, meaning that it can tell exactly when a measurement is taken, but that it is harder to decide where the electrical potential comes from. There are four types of brain waves, namely alpha, beta, theta, and delta waves.

For this experiment, 15 subjects are needed. We believe that 3 per day is a suitable number. Fewer subjects would mean less reliability and much more would mean a lot of paper work. The subjects are students, generally aged 18 to 25, both male and female. Ideally, we would have male and female subjects evened out. These subjects are divided into three groups: the group that will wear red glasses; the group that will wear blue glasses; and the control group, wearing no tinted glasses. Group red and group blue will be compared to the control group to detect any significant mood changes. Thus, there is only one variable and any others are going to be restricted. As to limit the possible variations caused by a change of the weather, news intake or other such disturbances, the experiment will take place on at least five different dates. On each day data from three subjects will be collected.

It has been determined that the glasses must be worn for several hours before the data collection, while the subjects pursue their daily activities. The beta lab is open on Wednesdays from 13:00 to 17:00, and on Fridays from 10:00 to 18:00. We would like to have the subjects wear glasses, preferably during three hours prior to the time of measurement. On the Wednesdays, data collection will start at four o'clock, and the subjects have to wear the glasses from one o'clock to that time. Measuring on Friday should start at the same time.

The mood of the subjects will be measured with EEG headsets in the afternoon. Participants will be exposed to three stimuli in the form of (possibly silent) black and white videos. This will be used to limit extra, undesirable influence by colours. There will be three types of black and white videos, happy or humorous, sad, and neutral videos. A video of the first category could be a clip of Charlie Chaplin, images of laughing people, or dancing people. The second category could be short clips of death scenes or scenes with sorrow. The last category will be comprised of, for instance, black and white nature videos or clips of newsreaders. The video clips have to be 3 minutes long and only the last two minutes of watching the video will be taken into account, because the subjects have to really get into the clip. After one movie, there will be a five-minute break to clear the mind of watching the video. In this break, subjects are not supposed to be too active. Besides this, we will also hand out a small questionnaire for the subjects to fill in at the start of the experiment and after the data collection. This could provide us with means of comparing behavioural and neural outcomes.

Conducting the experiment

Our experiment went almost entirely as planned previously. There was one small technical problem, namely that the movie clips were not playing. Fortunately, we found an alternative: showing black images and putting a laptop in front of the PC. We also reduced the amount of people from 15 to 12, both male and female, because we felt we had enough consistent results.

There are several possible confounding variables in our experimental design. Wearing the glasses for a whole day was proved to be related to a few drawbacks that might have had influence on the results. First, the coloured glasses used in the experiment differed from each other in shape. Therefore, the participants of the blue group had a different wearing experience than the ones from the red group. Some participants did report that it was uncomfortable to wear the glasses for such a long time due to their shape. Furthermore, some participants reported that seeing everything through the strong coloration of the glasses for such a long time was also “annoying”. This effect might have interfered with the possible other interactions of the colours on the subject’s mood.

Besides the possible disturbances of wearing the coloured glasses for several hours there are other effects that are likely to have an influence on the measurements. Even though, the experiments were always conducted at the same time of the day, elements like the weather or other personal factors have a big influence on the mood of a person that might need a bigger sample size than n=12 used in this experiment.

Other possible improvements concern the setup of the measurements. Due to difficulties with the software, for the first half of the subjects the video clips had to be started individually. This caused a relatively high “background noise” in the room and during the measurements which might have caused noise in the measurements.

In order to control for some of these extra variables in the experiment we therefore decided to include a short questionnaire that included items about the quality of sleep and close deadlines in the university as well as the perceived mood of the participants which had to be filled out in the morning and after the experiment.

Data analysis

Raw data from the EEG headsets during the experiment was obtained. These data were transformed to alpha, beta, theta, and delta waves. After pre-processing in Weka explorer the data was usable for comparing and recognising patterns. In the pre-processing unusual outliers were removed and the histograms resembled normal distributions. The used normalising algorithm can be found under unsupervised, attribute, and is called Interquartilerange. Setting the normalindices to 2 yielded the normalised data.

Firstly, the attribute colour of worn glasses is set as the class. A class is the attribute that is to be explained using the measurement data. To discover patterns in the pre-processed data a classifier was used. A classifier is an algorithm that performs such processes. Weka is equipped with a decision tree learning algorithm called J48. As mentioned before, J48 creates a tree that determines which attribute corresponds with which values. This is represented using a tree with nodes and leaves. Running the decision tree algorithm J48 on the data yielded as result that, based on brain activity, there is a high correlation between the F7-alpha wave and the blue glasses as variable. Supposedly, wearing blue glasses has a strong influence on the alpha waves in the frontal lobe of the brains. A percentage of 85% correctly classified instances was obtained, which means that the decision learning tree holds for 85% of the cases. If the instance of the F7-alpha wave was smaller or equal to 1.515, it correlates with blue. The tree then splits into F4-beta waves (1.426). If the number of the F4-beta wave was smaller or equal to 1.426 and the P8-beta wave smaller or equal to 0.933 it correlates with no glasses. If the P8-beta wave was higher than aforementioned number, the beta wave on the T7 location was smaller or equal to 1.121, and the beta-wave on the O1 location smaller or equal to 0.472, such a value for the O1 location would correspond to wearing red glasses, otherwise blue. If the T7-beta wave was higher than 1.121, it could be that FC5-beta waves are correlated to red glasses when its value was lower or equal to 1.549, or P7-beta waves (lower or equal to 1.251) are related to wearing no glasses.. Coming back to the F4-beta waves: if the found value was higher than 1.426, FC5-alpha waves lower than 2.201, it would be an indicator for wearing red glasses. Otherwise, when O2-beta waves are higher than 1.743, it means no glasses. When O2-beta waves are lower than or equal to 1.743, and F7-theta waves higher than 8.327, it corresponds to wearing no glasses. The textual result and the visualisation of the tree:

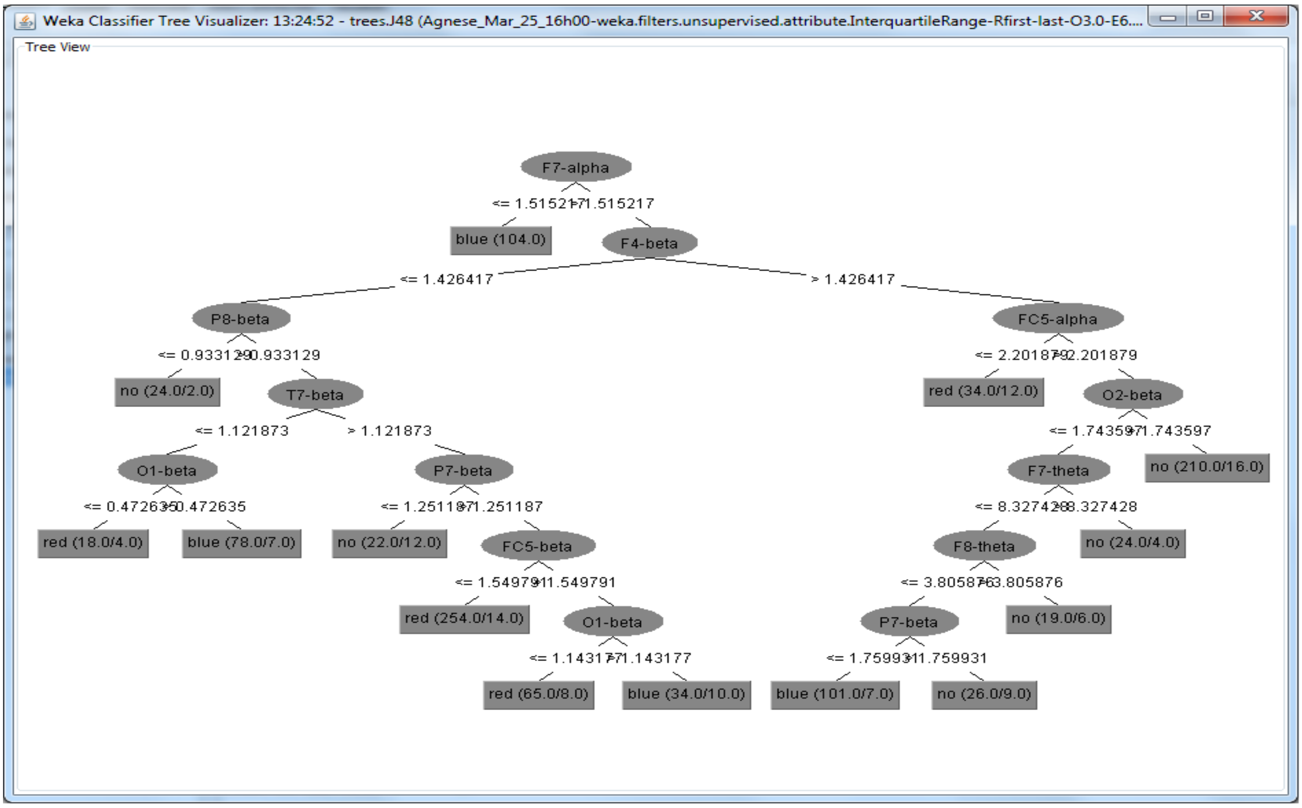
```
=== Run information ===
Scheme:    weka.classifiers.trees.J48 -C 0.25 -M 18
Relation:  Agnese_Mar_25_16h00-
weka.filters.unsupervised.attribute.InterquartileRange-Rfirst-last-
O3.0-E6.0-weka.filters.unsupervised.instance.RemoveWithValues-S0.0-
Clast-L2-weka.filters.unsupervised.attribute.Remove-R60-61-
```

```
weka.filters.unsupervised.attribute.Remove-R1,3
Instances: 1013
Attributes:   57
          color
          AF3-alpha
          AF3-beta
          AF3-delta
          AF3-theta
          F7-alpha
          F7-beta
          F7-delta
          F7-theta
          F3-alpha
          F3-beta
          F3-delta
          F3-theta
          FC5-alpha
          FC5-beta
          FC5-delta
          FC5-theta
          T7-alpha
          T7-beta
          T7-delta
          T7-theta
          P7-alpha
          P7-beta
          P7-delta
          P7-theta
          O1-alpha
          O1-beta
          O1-delta
          O1-theta
          O2-alpha
          O2-beta
          O2-delta
          O2-theta
          P8-alpha
          P8-beta
          P8-delta
          P8-theta
          T8-alpha
          T8-beta
          T8-delta
          T8-theta
          FC6-alpha
          FC6-beta
          FC6-delta
          FC6-theta
          F4-alpha
          F4-beta
          F4-delta
          F4-theta
          F8-alpha
          F8-beta
          F8-delta
          F8-theta
```

```
           AF4-alpha
           AF4-beta
           AF4-delta
           AF4-theta
Test mode: 10-fold cross-validation
=== Classifier model (full training set) ===
J48 pruned tree
------------------
F7-alpha <= 1.515217: blue (104.0)
F7-alpha > 1.515217
|   F4-beta <= 1.426417
|   |   P8-beta <= 0.933129: no (24.0/2.0)
|   |   P8-beta > 0.933129
|   |   |   T7-beta <= 1.121873
|   |   |   |   O1-beta <= 0.472635: red (18.0/4.0)
|   |   |   |   O1-beta > 0.472635: blue (78.0/7.0)
|   |   |   T7-beta > 1.121873
|   |   |   |   P7-beta <= 1.251187: no (22.0/12.0)
|   |   |   |   P7-beta > 1.251187
|   |   |   |   |   FC5-beta <= 1.549791: red (254.0/14.0)
|   |   |   |   |   FC5-beta > 1.549791
|   |   |   |   |   |   O1-beta <= 1.143177: red (65.0/8.0)
|   |   |   |   |   |   O1-beta > 1.143177: blue (34.0/10.0)
|   F4-beta > 1.426417
|   |   FC5-alpha <= 2.201879: red (34.0/12.0)
|   |   FC5-alpha > 2.201879
|   |   |   O2-beta <= 1.743597
|   |   |   |   F7-theta <= 8.327428
|   |   |   |   |   F8-theta <= 3.805876
|   |   |   |   |   |   P7-beta <= 1.759931: blue (101.0/7.0)
|   |   |   |   |   |   P7-beta > 1.759931: no (26.0/9.0)
|   |   |   |   |   F8-theta > 3.805876: no (19.0/6.0)
|   |   |   |   F7-theta > 8.327428: no (24.0/4.0)
|   |   |   O2-beta > 1.743597: no (210.0/16.0)
Number of Leaves  :  14
Size of the tree :  27

Time taken to build model: 0.22 seconds
=== Stratified cross-validation ===
=== Summary ===
Correctly Classified Instances       864               85.2912 %
Incorrectly Classified Instances     149               14.7088 %
Kappa statistic                      0.7786
Mean absolute error                  0.1412
Root mean squared error              0.2886
Relative absolute error              31.8345 %
Root relative squared error          61.2867 %
Total Number of Instances            1013
=== Detailed Accuracy By Class ===
           TP Rate   FP Rate   Precision   Recall  F-Measure   ROC
Area  Class
                0.826     0.056     0.879     0.826     0.852
     0.915 blue
                0.904     0.096     0.842     0.904     0.872
     0.937 red
                0.821     0.07      0.84      0.821     0.83
```

```
     0.919 no
Weighted Avg.    0.853     0.075     0.854     0.853     0.853
     0.924
=== Confusion Matrix ===
  a   b   c   <-- classified as
276  26  32 |   a = blue
 18 331  17 |   b = red
 20  36 257 |   c = no
```

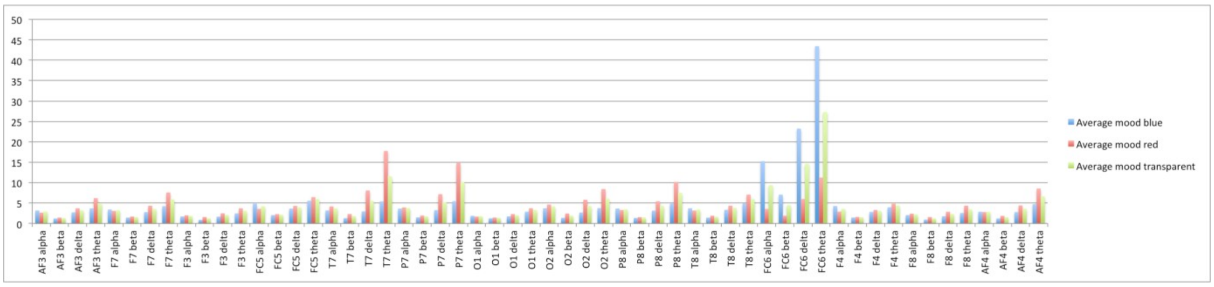


This figure shows that on the basis of F7-alpha waves the blue glasses are clearly identifiable, they have a lower distribution of values. The second split is at F4-beta, which leads to P8-beta and FC5-alpha. The tree can be interpreted likewise. Thus, a high F7-alpha, a low F4-beta, a high P8-beta, a low T7-beta and then a low O1-beta lead to a recognition of 18/4 on the red glasses. 18 correct classified instances was the minimum we used for the sample. 18/4 means that 18% of the 22 instances were incorrect and the others were correctly classified.

Important values are the blue under F7-alpha, because the recognition value is relatively high with a 104/0, which means that 104 instances got clarified correctly and zero were wrong on the basis of the training data. Another interesting value is the no 210/16, under O2-beta on the right and red with 254 under FC5-beta in the bottom of the left tree.

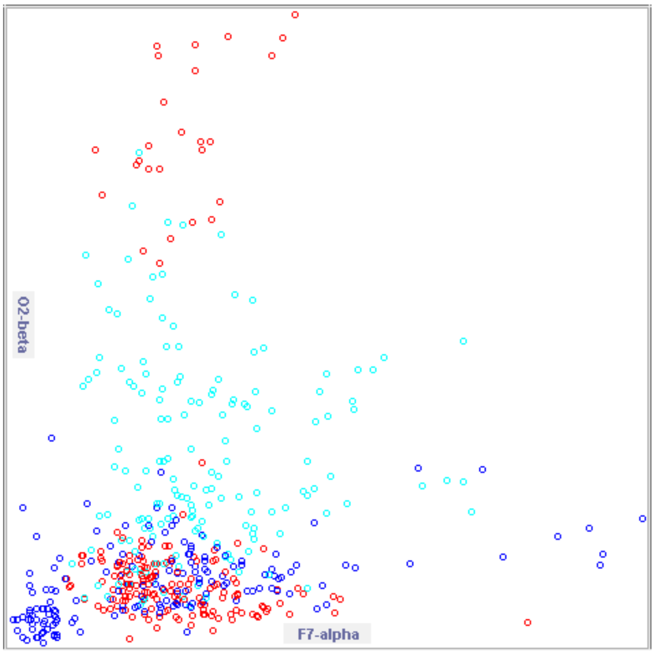
Lastly, the presumed mood that the shown video clips induced was set as the class attribute. Varying the confidence factor or the value for minNumObj in the J48 algorithm menu did not yield any distinct result as when setting the colour of the glasses as the class. The percentage of correctly classified instances was not higher than 60-70%. Thus, based on brain activity, there was no significant correlation between any wave type or any location and the type of video shown.

As the induced mood was not as much related to brain activity as the colour of the glasses was, it was decided that graphs depicting different waves and locations on the x-axis, and the magnitude of the perceived waves on the y-axis was possibly the best method of showing the results. For every colour of glasses, the found values were averaged over the duration of the video clips, the different subjects, and the three different moods. This resulted in the following graph:



It can be seen that blue glasses are related to high activity of the delta waves in the FC6 location and the alpha waves in the F4 location. The red glasses are related to delta waves in the T7 location and P7 location. This graph should be very reliable, because the high value found for blue glasses in the FC6-location is very representative for all the different mood videos, all the subjects wearing blue, and throughout the movie. The meaning of these findings can be found in the discussion.

This figure represents the distribution between values of the F7 alpha and the O2 beta locations:



In this figure blue spots correspond to the blue coloured glasses; red to the red coloured glasses and light blue correspond to neutral. As you can see, neutral stands out in this figure for values of the O2 beta and F7 alpha waves that are not particularly low or high, but rather in the middle. The small package of blue dots in the low right is also quite noticeable. We can see in the figure that a very low value of the F7 alpha wave is a good indicator for blue coloured glasses.

The analysis of the questionnaires did not yield any significant results, which was most likely due to the small sample size but might also have a variety of other reasons. Colour of the glass was entered as the independent variable into a simple regression analysis to predict levels of happiness. It did not significantly predict happiness $p=.826$. However, at a non-significant level, colour predicted 8% in the variance in happiness $F(1,12)=.033$, $p=.826$. The reported mean happiness of the red and the blue group was the same after wearing the glasses for a day. There was a correlation of .55 between the happiness in the morning and in the afternoon, indicating that the happiness levels where overall the same during the day. Having a close deadline or getting restful sleep did also not predict mood on a significant level.

Despite the non-significant results, including a questionnaire as an addition to the collection of EEG data can be a valuable addition to a study about mood. Future research would have to be based on a larger sample size and could then use the questionnaire as an additional control for other confounding factors to the experiment.

Discussion

J48 analysis of the EEG data showed significantly lower levels of F7-alpha activity in subjects wearing blue glasses, compared to those wearing red glasses and the control group. At the same time, FC5-alpha activity is found to be significantly lower in subjects wearing red glasses than in the other subject groups. This is somewhat contradictory, as F7 and FC5 are positioned adjacently on the left frontal lobe of the brain, and would be expected to show similar changes in alpha wave occurrence. Alpha waves typically emerge in the posterior part of the brain during the state of relaxation, low alpha wave activity consequently indicates arousal. In related research, Yoto et al. (2007) found lower levels of alpha band activity at FP1, F7, T5, and Fz in subjects looking at sheets of blue paper compared to those exposed to red colour, i.e. that exposure to red had a less arousing effect than looking at blue paper. Their findings are in opposition to a range of coloured light studies (Ueda et al., 2004; Shimagami & Hihara, 1991, 1992), in which red was found to be significantly more exciting than blue. The latter two studies used filtered illumination lamps (with illuminance levels of 150 lx and 40 lx, resp.) as stimuli, at both levels reporting a higher appearance rate for alpha waves with eyes under blue light. With regard to these studies, Yoto et al. (2007) argue that "the intensities of the colored lights that entered the eyes in the above experiments were weaker than was the case in [Yoto et al.'s] study, thus the biological activating effects of bluish light seemed not efficient enough to overturn the opposite results". In our study, the opposing findings for alpha waves at F7 and FC5 in subjects wearing blue glasses hinder a definitive conclusion. However, Yoto et al. (2007) conclude that given the lack of significant effects of colours on alpha band activity in the occipital lobe, where signs of arousal would be expected to occur, their findings that blue colour has a stronger arousing effect than red might not be conclusive, and that there might be other explanations for lower alpha band activity in the frontal lobe of subjects exposed to blue colour. As the same is true for our study, this tentative conclusion might be applicable in its case as well.

With regard to beta band activity, J48 results of our EEG data reveal significantly higher activity in subjects wearing blue glasses at O1, as well as lower activity in subjects wearing red glasses at O1, O2, and FC5. Beta activity is typically most evident in the frontal areas of the brain, and is linked to motor activity and arousal. Here, our findings are in direct opposition to those of the coloured light study by Ueda (2004), in which colour stimuli (red, white, and blue) created on a computer screen were represented via reflection in a mirror. This study reported higher beta wave intensity in the occipital lobe of subjects exposed to red, and lower intensity in subjects exposed to blue light. In accordance with the study Yoto et al. (2007), our findings would thus suggest higher arousal in subjects wearing blue glasses than in those wearing red glasses. Although this goes counter the suggestions made by psychological (especially ergonomic) studies based on self-report (e.g. Kwallek & Lewis, 1990), there is some support for this finding. In research on the effect of colour on the alpha attenuation coefficient, Noguchi et al. (1999) found that bluish light with a high colour temperature was associated with higher AAC values than was reddish light with a lower colour temperature, pointing towards higher arousal. Yoto et al. (2007), who report similar findings, point out that “light also mediates and controls a large number of biochemical processes in the human body”. According to research by Bommel and Beld (2004), biologically, bluish light has a larger activating or alerting effect than does reddish light. This mechanism might explain the stronger arousing effect of exposure to blue rather than red colour.

In summary, where colour differences in alpha and beta wave activity are significant, most findings - with the exception of lower FC5-alpha activity in subjects wearing red glasses – suggest that exposure to blue colour is linked to higher, and exposure to red colour to lower arousal. However, the results of the questionnaires we collected before and after the experiment are not significant, and do not point towards a difference in arousal between subjects wearing differently coloured glasses. As the differences in wave activity mostly occurred in areas where the respective waves are not expected to significantly indicate arousal, this could mean that there are other reasons for the observed differences.

Conclusion

To investigate the impact of different colours on mood, subjects were exposed to red and blue for the span of one day using coloured sunglasses, and their responses to emotional videos were measured using EEG devices. Additionally, questionnaires were used to investigate the subjects’ self-perception of their mood.

Using EEG, we find lower alpha wave activity in the frontal parts of the brains of participants exposed to blue, and lower beta wave activity in the posterior parts of the brains of participants exposed to red. This points towards a stronger arousing effect of blue than of red, in accordance to earlier studies (Yoto et al., 2007). However, the effects of colour exposure could only be found in parts of the brain which are not expected to strongly indicate arousal. We can therefore not conclude finally on the impacts of red and blue on arousal and, more broadly, mood.

Further research should investigate more closely the effects of colour exposure, in particular long-term, on brain activity and emotional responses to stimuli. Our study contributes to growing evidence that contrary to earlier psychological studies, blue has a more arousing effect than red, perhaps due to the importance of light as a mediator for biochemical processes in the human body.

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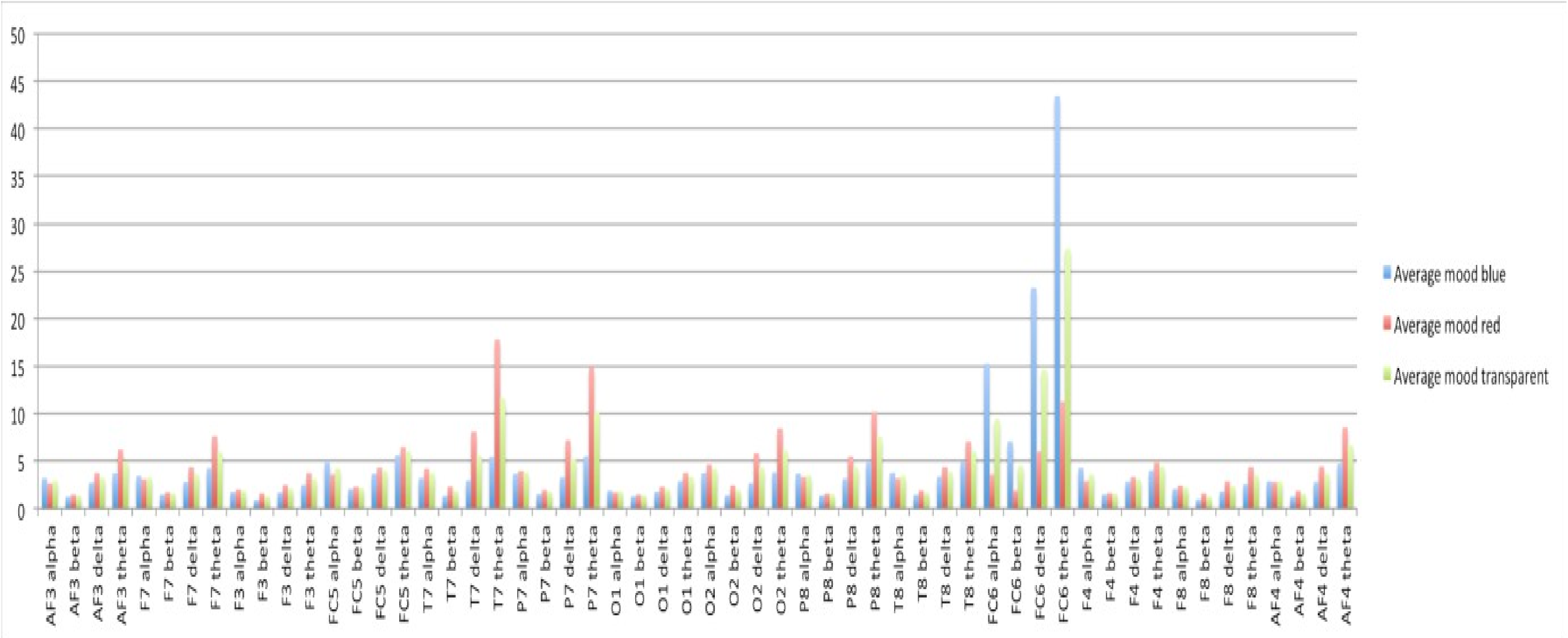
Appendix

1. Averaged EEG measures for different colours during video



2. Questionnaire

General - information questionnaire:

1. Age: ……

2. Gender: Male [ ] Female [ ]

3. Nationality: ……

4. What is your major:

Humanities (Communication, History etc.) [ ]

Social Sciences (Psychology, Economics etc.) [ ]

Sciences (Physics, Math etc.) [ ]

5. Do you have a deadline within the next 3 days? [ ]

Mood questionnaire morning:

Do not agree at all - I completely agree

	1	2	3	4	5	6	7
6. I feel stressed							
7. I am getting restful sleep							
8. I feel impatient							
9. I'm in a good mood							
10. I feel frustrated							
11. I feel angry							
12. I feel calm and relaxed							

13. I feel optimistic							
14. I feel happy and content							
15. I can think clearly							
16. I feel down							

Mood questionnaire afternoon:

Do not agree at all - I completely agree

	1	2	3	4	5	6	7
6. I feel stressed							
7. I am getting restful sleep							
8. I feel impatient							
9. I'm in a good mood							
10. I feel frustrated							
11. I feel angry							
12. I feel calm and relaxed							
13. I feel optimistic							
14. I feel happy and content							
15. I can think clearly							
16. I feel down							