STA490 2019-20 Fall Project Report:
The effects of auditory distraction on cognitive flexibility

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Summary

This report investigates the effects of auditory distraction on cognitive flexibility. In the experimental design, cognitive flexibility is measured by the difference between OnTime and OffTime measured by the EncephalApp Stroop Test app. For each of the measurements, the lower the difference, the higher the cognitive flexibility. Whereas auditory distraction occurs in three levels: quiet (control), instrumental music and music with lyrics.

It is found that different levels of auditory distractions have no significant effect on the cognitive flexibility of the subjects. On the other hand, the cognitive flexibility of subjects increases the more they attempt the tests, regardless of the levels of auditory distraction. This can be interpreted as the existence of a learning curve among the subjects, that is through repetitions the subjects become more familiar and efficient at the test. It is also found that the cognitive flexibility of the subjects is higher when experiments are conducted on Apple products (iPad tablet, iPhone/iPod). However, this result cannot imply hat Apple-using subjects have higher cognitive flexibility than Android-using subjects, and thus not much conclusion can be drawn.

Introduction

Cognitive flexibility is the ability of the brain to shift between thinking about different concepts or between different tasks(Braem and Egner, 2018). Previous research has suggested that cognitive flexibility may be related to creative problem-solving (DeHaan, 2009), recall and retention (Taconnat et al, 2009), and advanced knowledge acquisition (Spiro et al, 2012). The aim of this experiment is to investigate the hypothesis, stating that different levels of auditory distraction might have an effect on cognitive flexibility. In the experimental design, cognitive flexibility is measured by the difference between OnTime and OffTime measured by the EncephalApp Stroop Test app. For each of the measurements, the lower the difference, the higher the cognitive flexibility. Auditory distraction occurs in three levels: quiet (control), instrumental music and music with lyrics. The data is collected from 72 students who are enrolled in STA490 in 2019-20. The experiments are conducted by themselves using the EncephalApp Stroop Test app at their preferred time. They are instructed to complete the three Stroop tests under three levels of auditory distraction, with the order of levels been randomized.

In this report, a linear mixed model is fitted to answer the research question. This model is fitted with the levels of distractions, orders of levels and types of devices used, alongside with subject ID, which is included as a random effect. This model will explore the effect of these predictor variables on the cognitive flexibility of the subjects. The limitations of the experimental design and data analysis methods will also be discussed later in the report.

Methods

In the initial exploratory data analysis, graphical tools such as boxplots and histograms are used to examine the relationship between cognitive flexibility and auditory distraction. Boxplots and histograms are created to compare the cognitive flexibility of the subjects under different variables, including levels of distractions, orders of levels, number of years studying at an English institution, video game playing status, hours of sleep the night before, time of day, colour-blindness, types of devices used and types of headphones used. From this process, it is found that besides the levels of distractions, orders of levels and types of devices used also have a significant effect on cognitive flexibility.

For the analysis, we used a model that includes these three predictor variables. Although the order of levels and types of devices used are not related to the primary research question, given their significant effects, their inclusion may improve the model fit. For comparison, we also used a model that includes the levels of distractions as the only predictor variable. In the experimental design, each subject provided three results, hence there is no independence in the data and pseudoreplication may exist. It is found that the differences among subjects attribute 33.51% to the variability in cognitive flexibility.[1] In this case, a linear mixed model may be the most appropriate model to use.

[1] Refer to Appendix, Figure 2

This model is fitted with the levels of distractions, orders of levels and types of devices used, alongside with subject ID, which is included as a random effect. The random effect is assumed to follow a normal distribution with independent of the error term. The model also assumes that the intercepts differ randomly across the 72 subjects, but the cognitive flexibility changes with the levels of distraction. The model also has a UN covariance structure and different variances with levels of order, to get a better fit.

Results

As mentioned before, for comparison we have fitted a model that includes the levels of distractions as the only predictor variable. This model gives us a rather counterintuitive result, which is the subject's cognitive flexibility is lower under a control/quiet condition, whereas we would expect a subject's cognitive flexibility to be the highest under a control/quiet condition as there would be no auditory distraction. Therefore, the model we have fitted with the three predictor variables may be more adequate in analyzing this data.

	numDF	denDF	F-value	p-value
(Intercept)	1	141	155.38	0.00
newdist	2	141	2.99	0.05
order	1	141	4.75	0.03
device	2	69	3.53	0.03

Table 1. ANOVA Summary Table for Model

Table 1 is an ANOVA table that breaks down the components of variation. It shows that levels of distractions (newdist), order of levels (order) and types of devices used (device) are significant predictor variables of cognitive flexibility, given that their p-values are relatively low. It seems like the p-values for order of levels and types of devices used are lower than the levels of distractions, indicating that perhaps they have more effects on cognitive flexibility.

	Value	Std.Error	t-value	p-value
(Intercept)	11.7677268	1.7497848	6.7252422	0.0000000
newdistcontrol	0.6622960	0.8448558	0.7839160	0.4344043
newdistlyrics	0.0160896	0.7235346	0.0222375	0.9822899
order	-0.9012657	0.4123390	-2.1857396	0.0304852
deviceiPad tablet	-3.6384715	1.7900714	-2.0325846	0.0459449
deviceiPhone / iPod	-3.7884337	1.4464453	-2.6191337	0.0108296

Table 2. Fixed Effect Outputs for Model

Table 2 further elaborates the relationship between cognitive flexibility and the three predictor variables. From '(Intercept)', it can be inferred that the difference between OnTime and OffTime is 11.77 seconds when the level of distraction is classical music, the order of levels is 1 and the type of device used is android phone. It is also notable to mention that the greater difference between OnTime and OffTime indicates lower cognitive flexibility.

Level of auditory distractions

The level of auditory distractions seems to have no significant effect on the cognitive flexibility, given its estimates and p-values. Under music with lyrics condition, the estimate only increases by 0.016 (p-value = 0.982), indicating there is no difference in cognitive flexibility under the two music-playing conditions. Under the control/quiet condition, the estimate increases by 0.662 (p-value = 0.434), indicating there is a slight difference in cognitive flexibility under the music-playing and quiet conditions, but the difference is still not statistically significant.

Order in which the three levels of auditory distraction were used

Compared to levels of distraction, the order of levels seems to have more significant effects on the cognitive flexibility. The estimate decreases by 0.901 (p-value = 0.030) when order of level increases by 1, meaning that the difference between OnTime and OffTime decreases as the test is conducted later within the three attempts. This also implies that the later the subjects conducted a test, the higher cognitive flexibility they have.

Types of devices used

The type of devices used to conduct the experiment also seem to have significant effects on the cognitive flexibility. When using an iPad tablet, the estimate decreases by 3.638 (p-value = 0.046), whereas when using an iPhone/iPod, the estimate decreases by 3.788 (p-value = 0.011). These are the biggest changes in difference between OnTime and OffTime we have seen, indicating types of devices used is a highly significant predictor variables.

Conclusion & Discussion

In the model, it is found that order of levels and types of devices used are variables that are more statistically significant than levels of distraction. It is found that different levels of auditory distractions have very little to none effect on the cognitive flexibility of the subjects, which answers the primary research question. This model also provides an interesting insight; the later the subjects did the tests among the three attempts under different conditions, the higher their cognitive flexibility becomes. This can be interpreted as the existence of a learning curve among the subjects, that is through repetitions the subjects become more familiar and efficient at the test. It is also found that the cognitive flexibility of the subjects is higher when experiments are conducted on Apple products (iPad tablet, iPhone/iPod). However, I do not think this result can imply hat Apple-using subjects have higher cognitive flexibility than Android-using subjects, and thus not much conclusion can be drawn.

There are two main limitations to the experiment. The first is the model sensitivity to the decision made in data cleaning. By removing or replacing values into the model, a different amount of bias can be introduced to the model. The second is the presence of the carryover effect, that is the order in which the levels of distraction is used in the three attempts may affect the outcomes of the experiment. Carryover effect occurs when the effect of an experimental condition carries over, influencing performance in the subsequent condition.

For future experimental design, this effect can be reduced by increasing the amount of time in between the subjects' attempts. It could be imposed by giving the subjects at least a 20-minute break in between attempts.

Appendix

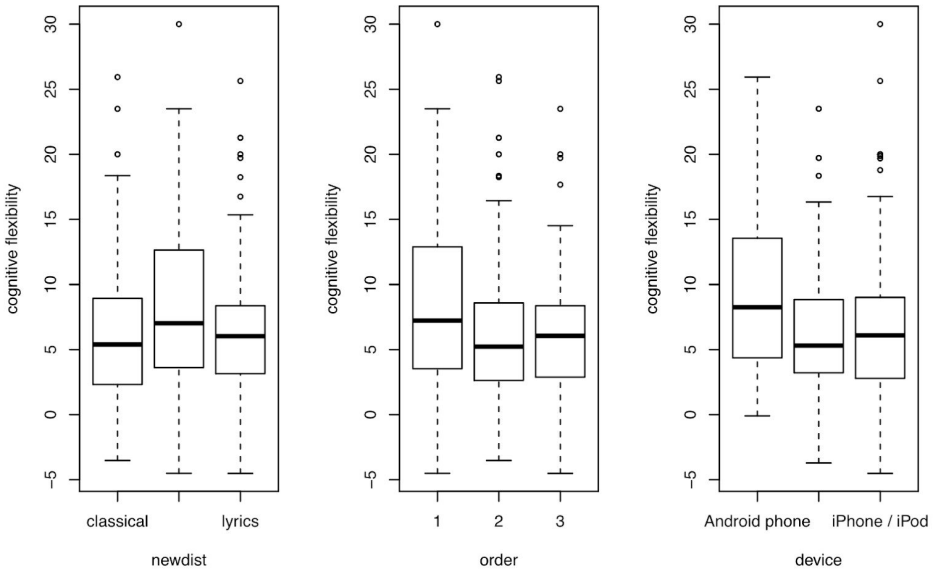

Figure 1. Boxplots indicating cognitive flexibility under three variables

	Variance	StdDev
(Intercept)	14.81129	3.848544
Residual	29.38215	5.420530

Figure 2. R Outputs for Random Effects in Model