The relation between Executive Functions, Depression and Anxiety Moderated by Visual Complaints

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Depression and anxiety often occur together and are considerably prevalent worldwide (Buckman et al., 2018). Several studies indicate that depression and anxiety are related to decreased quality of life, interpersonal difficulties, lower occupational or academic achievement, and chronic diseases such as heart disease (Gao et al., 2019; Goodman et al., 2019; Hauenstein, 2003; Hogg et al., 2021; Tsabedze et al., 2021). Some studies even come to the conclusion that depression causes functional disability and an elevated risk of physical health issues (Buckman et al., 2018). Additionally, depression and anxiety have been found to be strongly associated with problems in cognition such as executive functions (Ahern & Semkovska, 2017; Demetriou et al., 2021; Rock et al., 2014; Snyder et al., 2019).

Healthy cognition especially executive functions (EF) are crucial for our daily lives. Executive functions are defined as goal-oriented mental processes, such as working memory, attention shifting, and response inhibition (Demetriou et al., 2021). An impairment in EF can have severe consequences on social and occupational life and is related to psychopathology and brain disease. Furthermore, it is suggested to be a risk factor or marker for several mental and neurological disorders (Snyder et al., 2015).

An impairment in overall EF, for instance, is associated with and suggested to be a risk factor for psychopathology. A persistent finding so far has been a relation between impaired EF and anxiety as well as depressive symptoms (Ahern & Semkovska, 2017; Demetriou et al., 2021; Rock et al., 2014; Snyder et al., 2019). This relationship, however, is still not well understood. Problems in EF can significantly increase life stress and some studies suggest that this mechanism might explain why impaired EF is a risk factor for psychopathology and in particular for depression and anxiety (Snyder et al., 2019). However, the directionality of the relationship between EF deficit and depressive and anxiety symptoms has only been studied scarcely. Some studies even discuss a possible bidirectional association between lower EF and higher anxiety and depression levels and advise to also consider mediator and moderator variables in future studies (Snyder et al., 2019).

Another health issue that is associated with EF deficits is vision impairment. Several studies have found that vision impairment and EF problems often coincide. Additionally, deficits in vision have been established as a risk factor for cognitive decline and neurodegenerative disease (Fischer et al., 2016; Whitson et al., 2014). Fisher et al. (2016), for instance, examine the relationship between sensory loss and cognitive decline with a 10-year longitudinal design including 1884 participants without prior EF impairment. They came to the conclusion that among other sensory deficits, visual impairment is independently related to the risk of cognitive decline. Even though research so far has found that vision deficits precede cognitive decline, possible third variables mediating this relationship

cannot be ruled out. Whitson et al. (2014) findings suggest that people, especially older adults and women, suffering from impairment in EF and vision are at higher risk of having difficulty in daily life activities as well as higher depressive symptoms. This is in line with research showing that depressive and anxiety symptoms are prevalent in people with visual problems (Bernabei et al., 2011; Binder et al., 2020; Kempen & Zijlstra, 2014). Similar to Whitson et al. (2014), an age and gender effect has been found showing that older adults and women have an increased risk of additionally suffering from depression and anxiety symptoms when vision impairment is present (Bernabei et al., 2011; Kempen & Zijlstra, 2014).

The present study

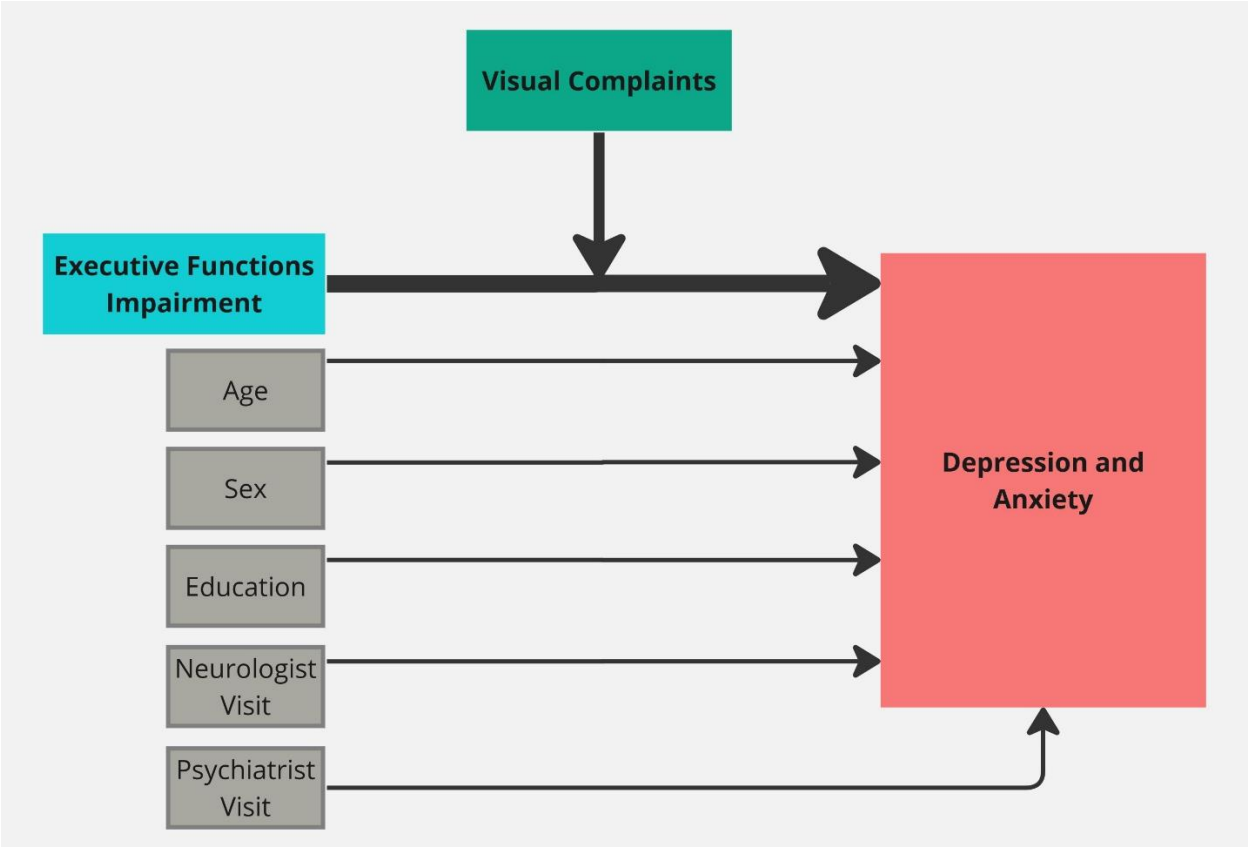
Since deficits in EF as well as in vision are both risk factors for depression and anxiety, screening for them in people that do not meet the clinical threshold for these mental disorders yet, would aid in identifying risk groups. Targeting the identified people at risk would improve the prevention of the clinical onset of these mental disorders. Therefore, it would be helpful to examine whether EF and vision impairment are already associated with depressive and anxiety symptoms in a sample of people with preclinical levels.

The aim of the present study is, thus, to assess whether a relationship between deficits in EF, as well as vision, and depressive and anxiety symptoms can be established in a self-proclaimed healthy sample. Additionally, the role of visual complaints as a moderator in the relationship between EF and anxiety and depression levels will be investigated. In order to do this, we will use data from Huizinga et al. (2020), in which the Screening of Visual Complaints questionnaire was evaluated using a convenience sample of self-reported healthy Dutch participants.

We will conduct a regression analysis using the total scores of the Behavior Rating Inventory of Executive Function-Adult (BRIEF-A), the Screening of Visual Complaints (SVC) questionnaires, and their interaction as explanatory variables to predict the outcome variable the total score of the Depression Anxiety Stress Scale– 21 (DASS-21). The model is visualized in Figure 1. Considering the finding that women and older adults are more likely to develop depression and anxiety in addition to EF and vision impairment (Bernabei et al., 2011; Kempen & Zijlstra, 2014; Whitson et al., 2014), age and sex will be included as control variables in the model. Since people who have visited a neurologist or psychiatrist have a higher risk of showing or developing depressive and anxiety symptoms, prior visits to a neurologist and psychiatrist will also be included as covariates. Additionally, education level will be included as a control variable due to the association between lower education and depression and anxiety (Bjelland et al., 2008; ten Kate et al., 2017)

Figure 1

Visualization of Statistical Model



Method

Design

The data was taken from the study by Huizinga et al. (2020). The study is a cross-sectional online questionnaire study to validate the Screening of Visual Complaints questionnaire in healthy Dutch participants. The sample was a convenience sample. All participants volunteered to participate and filled out the same questionnaires for the study. Therefore, this was not an experiment and there was no assignment to different conditions.

Participants

From the total dataset of 1,461 self-proclaimed healthy Dutch participants, 400 randomly selected observations were used for the data analysis in the present report. The participants were recruited via a company that gives financial rewards for participating in online research. Participants were included in a way that their age (*M* age = 55.16, *SD* = 18.33), sex (52.75 % female), education level (*Mdn* level = Medium), and amount were equally distributed within age clusters of ten years. Therefore, the sample is a stratified convenience sample. Education level was assessed by asking what the participant's highest level of education is and categorized into 10 levels. The lowest level is less than the 8th class of Dutch education and the highest level is owning a master's degree. These 10 levels were then summarized into the categories low, medium, and high, it was, however, not specified how these categories correspond to the 10 levels. Additionally, participants were asked whether they had been to a psychiatrist or neurologist. Most participants had neither been to a psychiatrist (69 %) nor to a neurologist (75%). Participants younger than 18 years old, with a severe neurological disorder, ophthalmological disease, or severe psychiatric disorder were excluded. All necessary information was collected through self-report.

Population

The sample is a stratified convenience sample. The population of the sample is representative of healthy Dutch citizens over 18 years that voluntarily participate in research for a financial reward. The population of interest on the other hand is healthy adult Dutch citizens. The participants participated on a voluntary basis instead of being randomly selected, thus bias due to some underlying factor specifically motivating these participants to take part in the study cannot be excluded. The sample is, therefore, only in part representative of the population of interest.

Instruments

Screening of Visual Complaints (SVC)

My moderator variable is the total score on the Screening of Visual Complaints (SVC). The Screening of Visual Complaints is a Dutch questionnaire that includes 21 items on visual complaints. It was developed by a group of experts from different clinical fields related to visual deficits in neurodegenerative disorders as well as patients suffering from neurodegenerative disorders. In addition to the suggestions of the expert group, the 21 items were based on frequently reported daily visual complaints of patients suffering from Parkinson's disease and multiple sclerosis on an old version of the Cerebral Visual Complaints questionnaire. These symptoms were double, shaky or unclear vision, depth perception or reading issues, difficulties with bright or dim light, and reduced visual field.

The SVC asks participants to base their answers on the last weeks. If the participants use corrective lenses, they are asked to answer as if they are using them on all items except for the first,

which categorizes the participant into different visual complaints categories such as wearer of corrective lenses or experiencing dry eyes. The following 19 items have the answer options 'no/hardly ever' (0), 'sometimes' (1) or 'often/always' (2). One example of an item is item 4: Do you have double vision or see double images? The last item asks the participant to estimate their daily disability as a result of visual complaints from 0 (none) to 10 (severely disabling). Several covariates such as demographic information on age, sex, and education as well as ophthalmological medical history are also measured by the SVC. The total score on the SVC is the sum score of the 19 structured items and its possible range is from 0 to 38. The larger the total score the higher the severity or number of visual complaints.

Validities and Cronbach's alpha were calculated for the original dataset of 1,461 participants. The convergent validity was checked by correlating the results with similar visual questionnaires and showed high correlations (r = 0.84, r = - 0.71). The divergent validity was calculated by correlating the results on the SVC with the BRIEF and the DASS. These were less strongly correlated, except for a subscale on the SVC related to worries about one's eyesight (BRIEF-A: r = 0.29; DASS-21: r = 0.34). The Cronbach's alpha in the original dataset was 0.85.

Behavior Rating Inventory of Executive Function—Adult (BRIEF)

My first explanatory variable is the total score on the Behavior Rating Inventory of Executive Function—Adult (BRIEF-A). The Behavior Rating Inventory of Executive Function is a questionnaire evaluating the executive functions of adults in daily life. The questionnaire includes 75 items that assess the indices of metacognition and behavioral regulation on a 3-point Likert scale from 'never' (1), 'sometimes' (2) to 'often' (3). The items, for instance, ask whether one makes careless errors when completing tasks or whether one has trouble changing from one activity or task to another. The total score is the sum score of the metacognition and behavioral regulation indices and ranges from 70 to 210. A higher total score shows higher executive function deficits.

The BRIEF-A also includes three validity scales which were used to exclude participants that scored higher than the cut-off score on one of these scales. The Cronbach's alpha for a normative healthy sample of 1,050 participants from the USA was 0.80 (Roth et al., 2014). The scales and indices were moderately related to each other (r = .44 - .68). The correlation with similar questionnaires such as the Dysexecutive Questionnaire was reported to be positive, but no correlation coefficient was disclosed. Discriminant validity was not mentioned in the study (Roth et al., 2014).

Depression Anxiety Stress Scale– 21 (DASS)

My outcome variable is the total score on the Depression Anxiety Stress Scale– 21 (DASS-21). The Depression Anxiety Stress Scale is a questionnaire evaluating depression, anxiety, and stress symptoms. There are seven items for each of these categories of symptoms. The answer options on a

4-point Likert scale are ‘never’ (0), ‘sometimes’ (1), ‘often’ (2) or ‘very often’ (3). One item, for instance, item 10 is: I felt that I had nothing to look forward to. The total score is the sum score of all items and ranges from 0 to 63. A larger total score signifies higher symptom severity and amount.

In a sample of 1,794 voluntary UK participants, the Cronbach’s alpha was 0.93 (95% CI = .93–.94) for the total scale (Henry & Crawford, 2005). The correlations between DASS and similar measures such as the Hospital Anxiety and Depression Scale (HADS) in a non-clinical UK sample of 1,771 were high (r = .66 - .78). To calculate divergent validity, differing constructs such as anxiety from DASS and depression from the HADS were correlated. The correlation coefficients were moderate, ranging from .49 to.59 (Crawford & Henry, 2003).

Demographic variables

The demographic variables that I choose to include in this report from the original dataset are age, sex, education level, visit to a neurologist, and visit to a psychiatrist. Age ranges from 18 years to 95 years. Sex has two levels male and female, of which male was coded with 1 and female was coded with 2. The included education level variable has the three levels low, medium, and high and these categories were coded with 1,2 and 3 respectively. The categories are based on a 10-level scale ranging from 1 less than 8th class of Dutch education to 10 owning a master’s degree. The authors of the original dataset did not specify how the 10 levels were categorized into low, medium, and high. The question to assess education level was: What is your highest level of education. Visit to a neurologist and visit to a psychiatrist have the two levels yes and no. The levels were coded with 1 for no and 2 for yes. To evaluate visit to a neurologist or psychiatrist, it was asked whether the participants have ever visited a neurologist or psychiatrist. The study of the original dataset does not describe how age and sex were assessed other than by means of self-report (Huizinga et al., 2020).

Procedure

The participants were recruited by a company giving a financial reward for participating in online research or polls. The participants volunteered to participate and completed the questionnaires online, which took around 40-50 minutes to finish.

Statistical Analysis Plan

The research hypothesis of the current report is that visual complaints work as a moderator variable in the relationship between executive function deficits and depression and anxiety levels. Thus, I expect participants that have more visual complaints to also have higher executive function deficits and depression and anxiety levels than participants with less visual complaints.

My outcome variable is the total score on the Depression Anxiety Stress Scale– 21 (DASS-21). My first explanatory variable is the total score on the Behavior Rating Inventory of Executive

Function—Adult (BRIEF-A) and my moderator variable is the total score on the Screening of Visual Complaints (SVC). On all the non-demographic variables higher values mean increased deficit.

I am planning to conduct a multiple regression analysis with the explanatory variables BRIEF and SVC and their interaction as a moderator variable. The dependent variable will be the total scores on DASS. The R version 4.1.0 (2021-05-18) is going to be used.

The assumptions of normality, linearity, and homoscedasticity will be checked. Additionally, the data will be examined for influential observations and the predictors will be inspected for multicollinearity. The normality assumption will be examined visually by plotting the standardized residuals of the model in a quantile-quantile plot. The homoscedasticity and linearity assumptions will be inspected with a scatterplot showing the predicted values against the residuals of the model. Influential observations that are significant on the difference in fit as well as on cook's distance will be further inspected. A new analysis without these influential points will be conducted and it will be examined whether the results differ substantially from each other. If they differ it will be examined and argued whether it is reasonable from a theoretical point of view to take these influential observations out of the analysis. Unless there is a theoretical sensible reason to exclude the influential observations from the analysis, the influential points and their influence on the results will be mentioned but they will be included in the analysis. The multicollinearity will be examined with the variance inflation factor (VIF). A VIF of more than 10 will be regarded as the cutoff for an undesirably large multicollinearity. If the VIF is higher than 10, the predictors will be centered. The significance level for all analyses will be an alpha of 0.05. Cohen's (1992) indexes for effect sizes will be used as a guideline for the interpretation of effect sizes.

Power analysis of Multiple Regression Model

The pwr R package was used to calculate the sensitivity of the analysis. An alpha of 0.05 was chosen. The degrees of freedom were taken from the results of the multiple regression analysis. The first degree of freedom was 8 and the second 326. The calculated smallest detectable effect size is 0.0459. This means that the effect size must be at least 0.0459 to be significant in our analysis.

Results

Data description

Missing Data

Several observations were found to be missing. From the variable education, 0.5% of observations were missing. This small amount was judged to be negligible. From the variable BRIEF total score, 13.75% of observations were missing and from the variable DASS total score, 15.75% were missing. For the missing data on BRIEF and on DASS categorical missingness variables were

created with 1 for missing values and 0 for available values. It was tested with chi-square tests whether the missingness variables of the BRIEF and DASS total scores are related to any variables. The only significant test was when the missing data were compared with each other (X^2 (1) = 333.79, p <.001, w = 0.914). The other chi-square tests were not significant, thus there is no evidence of a strong relationship between the missing data and other variables in the model (X^2 (1) = 0.06-0.81, X^2 (2) = 2.93- 3.53). This poses a problem as the missing data are not related to our observed data and, thus, the data may not be missing at random.

Descriptives

Table 1 shows the mean, standard deviation, trimmed mean, and median absolute deviation for the continuous variables in the model. While the range for BRIEF is 70 to 210, the mean and trimmed mean are 92.96 and 90.55. This indicates that most participants scored in the lower range of the BRIEF scale. Similarly, SVC with a range of 0 to 38 has a low mean and trimmed mean of 5.57 and 4.89. DASS ranging from 0 to 63 also has a low mean and low trimmed mean of 6.58 and 5.11. Additionally, SVC and DASS have a small spread as indicated by their standard deviations and their median absolute deviations, which are very close to their means and trimmed means. This indicates that the majority of scores on SVC and DASS fall on the very low range of the scales. Age has the range of 18 to 95 and its mean and trimmed mean are around 55. This implies that most scores fall around the middle of the possible range. The standard deviations and median absolute deviations of BRIEF and age are larger than those of SVC and DASS. This suggests that the scores on BRIEF and age are more spread out. The differences between the means and the trimmed means are quite small on the variables SVC and DASS compared to BRIEF and age. A possible explanation for this smaller difference between the mean and the trimmed mean is that the variables SVC and DASS are more strongly skewed than BRIEF and age.

Table 2 outlines the correlations between the continuous variables. As expected, visual complaints (SVC) and EF deficits (BRIEF) are positively related to depressive and anxiety symptoms (DASS). The correlation between DASS and BRIEF scores is the strongest relationship of all and has a large effect size according to Cohen's (1992). The next strongest correlation is between DASS and SVC, followed by the relation between BRIEF and SVC and both have a medium effect size. Surprisingly, DASS scores and age as well as BRIEF and age are negatively related to each other and have a small effect size. On the other hand, age, and visual complaints (SVC) are, as can be expected, positively correlated, with a small effect size.

Table 1.

Descriptive Statistics Continuous Variables

Variables	*M*	*SD*	*triM*	*Mad*
BRIEF	92.96	18.43	90.55	16.31
SVC	5.57	5.03	4.89	4.44
DASS	6.58	8.03	5.11	4.45
Age	55.16	18.33	55.89	20.76

Note. triM = 0.2 trimmed mean, Mad = median absolute deviation, BRIEF = total scores on Behavior Rating Inventory of Executive Function—Adult, SVC = total scores on Screening of Visual Complaints, DASS = total scores on Depression Anxiety Stress Scale– 21

Table 2.

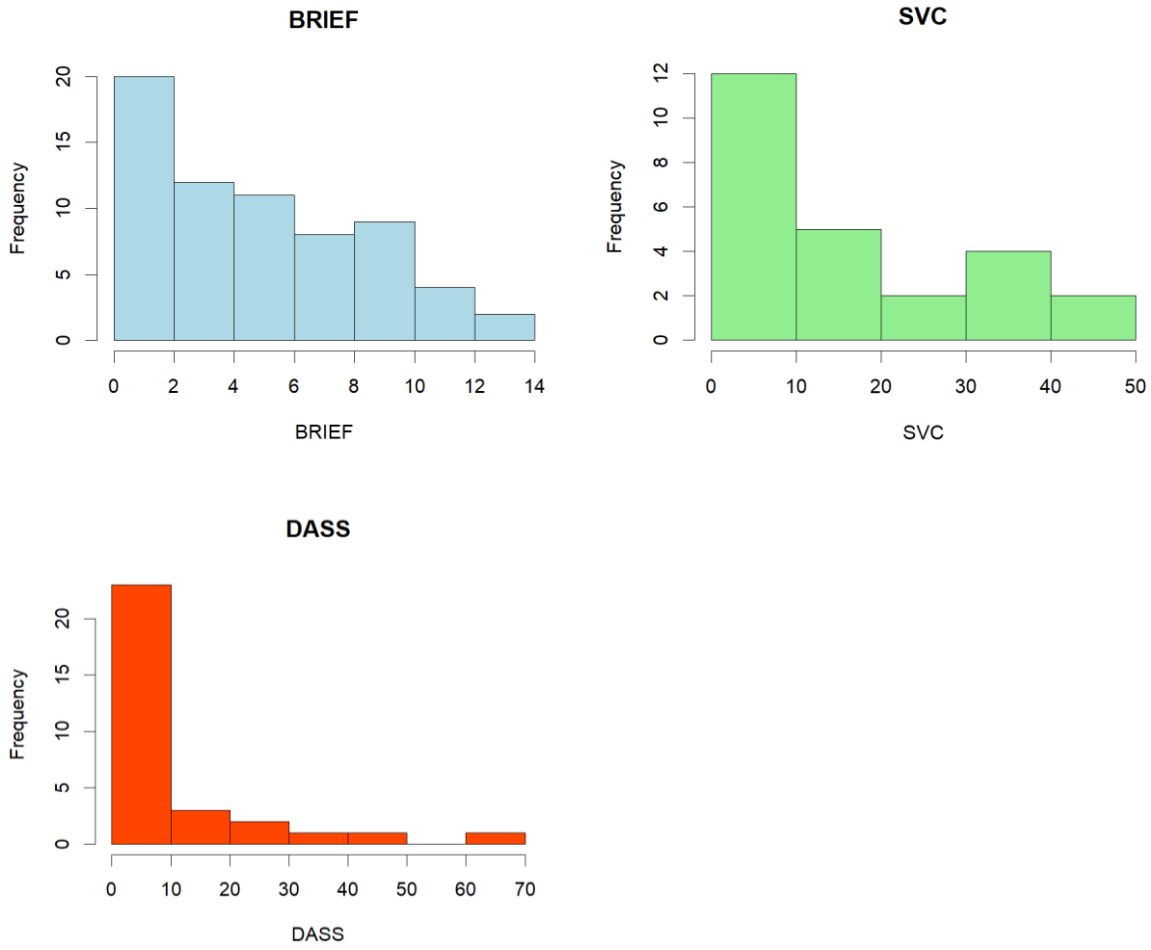
Correlations for Continuous Variables

Variable	1	2	3	4
1. BRIEF	—			
2. SVC	.29	—		
3. DASS	.69	.37	—	
4. Age	-.11	.10	-.12	—

Figure 2 shows bar plots of the continuous predictors and the outcome variable of the model. It shows that the data on the predictor and outcome variables are strongly right skewed. This non-normality of the data hints at a possible violation of the normality of residuals. This can be explained by the fact that the questionnaires measuring executive function and visual deficits as well as depressive and anxiety symptoms were administered to self-proclaimed healthy participants. Since healthy participants are less likely to experience mental health and cognition issues, they will score lower on questionnaires measuring executive function and vision deficits as well as depressive and anxiety symptoms. Additionally, as these participants volunteered to participate in a study for healthy participants, they might be less likely to report mental health or cognition problems even if these are present. Furthermore, after proclaiming oneself to be healthy one might be more likely to downplay mental illness or cognitive deficits while answering the self-report questionnaires.

Figure 2

Distribution of Data on the Variables BRIEF, SVC and DASS



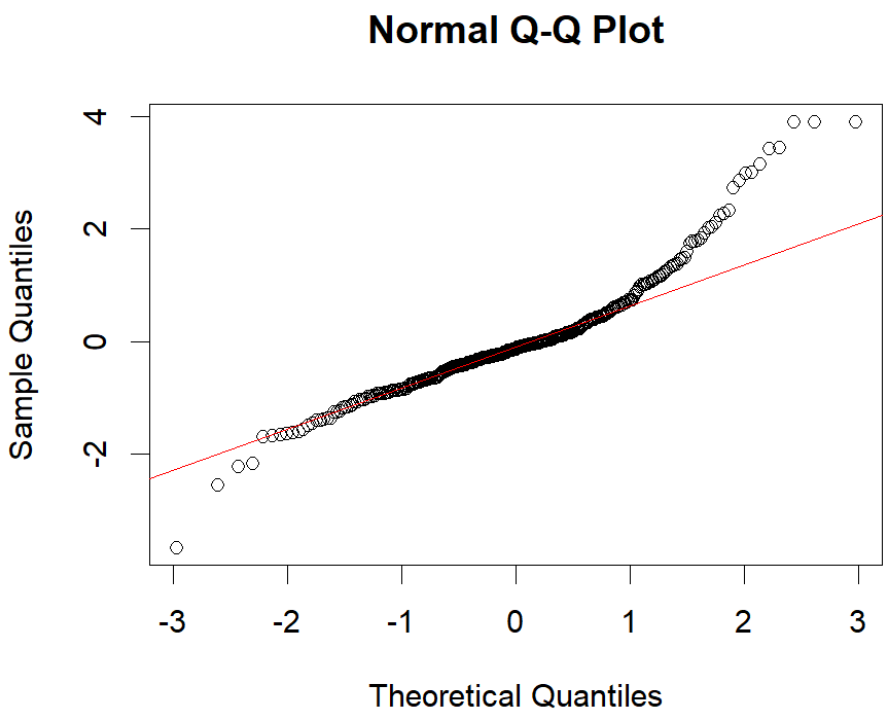
Assumptions of Multiple Regression Model

The normality, homoscedasticity, and linearity assumptions for the multiple regression model were checked. Additionally, the continuous predictors were centered to reduce multicollinearity and the data was inspected for possible influential observations.

The normality of residuals was examined graphically with a quantile-quantile plot. In figure 3 this quantile-quantile plot of the standardized residuals of the multiple regression model is shown. The plot shows an elongated s-form of the quantiles. In the middle the points fall on the reference line, the tails, however, deviate quite strongly from the reference line. This indicates that there are more extreme values at the tails of the residual distribution of the model than one would expect if the residuals of the data were normally distributed.

Figure 3

Quantile-Quantile plot of Residuals

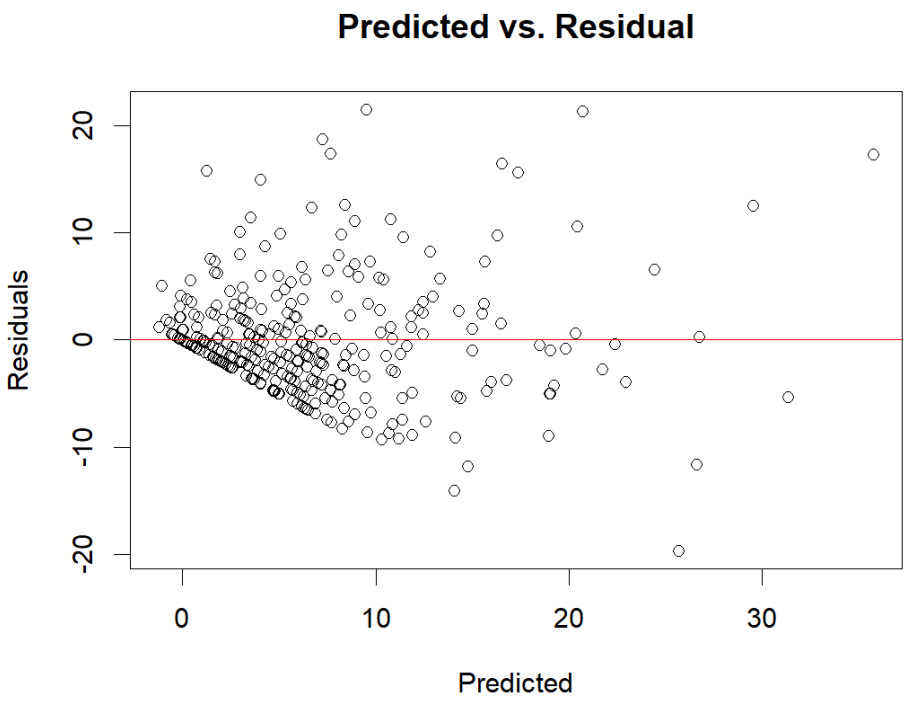


The homoscedasticity assumption was checked graphically by plotting the residuals against the predicted values of the model. Figure 4 shows the plot of residuals against predicted values. As can be seen, the dots are much more clustered around the zero line on the left and spread out more and become less towards the right of the plot. This shows that the spread of the residuals is not equal for all predicted scores. The plot, thus, shows a strong violation of homoscedasticity.

The assumption of linearity between the dependent and independent variables was inspected visually with the same residuals against the predicted values plot (see Figure 4). The mean values should be about the same across the graph and should fall close to the 0 line. In figure 4, however, the mean values start at the 0 line on the left but deviate more towards the middle and right of the graph. This can be seen by the densely clustered dots on the left that form a black diagonal line. Therefore, the dots do not fall randomly around the 0 line, which signals a violation of the linearity assumption of the continuous predictors.

Figure 4

Plot of Predicted Values Against Residuals



The variance inflation factor was higher than 20 for the SVC total score and the interaction between the BRIEF and SVC total scores. After centering the predictors, the VIF was reduced substantially and was lower than 1.3 for all predictors.

The difference in fit and cook's distance together were used to decide whether an observation should be considered as a possibly influential point. No observation was determined to need further inspection.

Due to the violations of normality and homoscedasticity, I decided to convert my outcome variable total scores on the Depression Anxiety Stress Scale (DASS) into a dichotomous variable and use a logistic regression with the explanatory variables BRIEF and SVC total scores, the interaction between these two variables and the control variables age, gender education level, visit to neurologist and visit to a psychiatrist.

Logistic Regression Analysis

The outcome variable DASS was split into the categories low and high. To have more balanced category sizes, I chose to include all scores from 0 to 3 in the low category and scores from 4 to 63 in the high category. Choosing to include different scores such as only 0 in the low group and 1 to 63 in the high category, does change the coefficients quite a bit, but would make the category sizes

extremely unequal, which would be unfavorable for a logistic regression analysis. The two categories of the dichotomized outcome variable were automatically coded by R as 1 for low and 2 for high.

The multicollinearity of the predictors was checked with the variation inflation factor. The centered predictors were used in the model and the VIF was lower than 1.31 for all predictors. No possible influential observations were detected by both cook's distance and difference in fit.

Figure 5 shows the component plus residual plots for each continuous variable and the interaction between BRIEF and SVC. In these plots the continuous predictors are plotted against their component-plus-residual. The linearity assumption was checked visually by examining figure 5. The mean values of the scatter follows more or less a line. Thus, there is no evidence for the violation of linearity.

Figure 5

Component plus Residual Plots

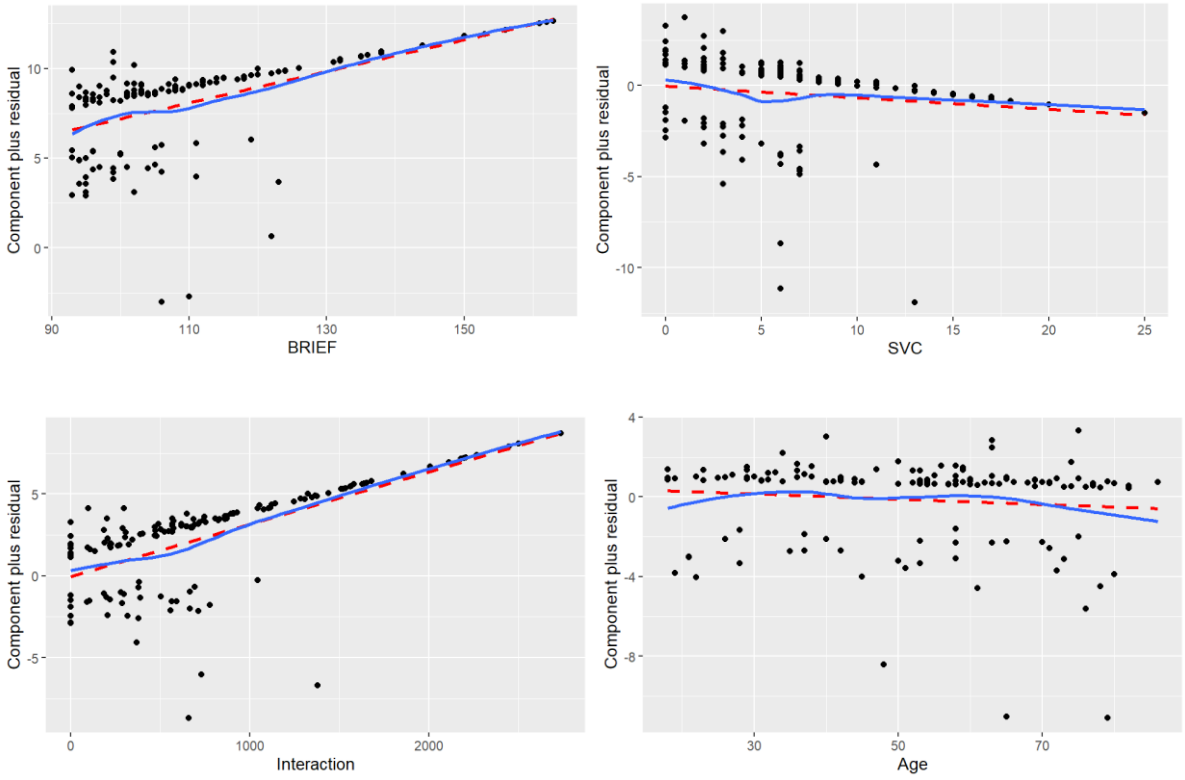


Table 3 displays the coefficients, their p-values and standard errors, z-values and 95% odds ratio confidence intervals of the logistic regression analysis. The only coefficient estimates that were statistically significant were the centered BRIEF and SVC coefficients. The centered interaction term was not significant and provided, thus, no support for my hypothesis. The highest odds ratios, other

than the intercept, is the odds ratio of the psychiatrist variable. It indicates that participants that have been to a psychiatrist before, have 1.258 higher odds of being in the high DASS total score category, which includes all scores higher than 3 on the DASS.

Table 3

Logistic Regression Analysis Results

Effect	Estimate	*SE*	Z-value	Oddsratio	95% CI Oddsratio		*p*
					LL	*UL*	
Continuous variables							
Intercept	1.207	.976	1.236	3.343	.493	22.661	.22
cBRIEF	.069	.011	6.370	1.072	1.049	1.095	<.0001
cSVC	.135	.037	3.617	1.145	1.064	1.232	<.001
cInteraction	.002	.003	.792	1.002	.997	1.007	.428
Age	-.010	.008	-1.322	.990	.975	1.005	.1862
Categorical variables							
Sex	-.147	.275	-.533	.864	.503	1.481	.594
Education	-.199	.180	-1.109	.819	.576	1.166	.268
Neurologist	-.001	.315	-.005	.998	.538	1.853	.996
Psychiatrist	.229	.304	.754	1.258	.693	2.281	.451

Note. CI = confidence interval; *LL* = lower limit; *UL* = upper limit; cBRIEF = centered BRIEF total scores; cSVC = centered SVC total scores; cInteraction = interaction between BRIEF and SVC total scores; Neurologist = visit to a neurologist; Psychiatrist = visit to a psychiatrist.

Discussion

The present report examined whether there is a relationship between visual complaints, deficits in executive functions, and depressive and anxiety symptoms in a healthy sample. Additionally, it was assessed whether visual complaints moderate the relationship between executive functions and depression and anxiety.

The results suggest that EF and visual deficits are positively related to depressive and anxiety symptoms. They indicate that participants who have executive function deficits are to a small degree more likely than participants without EF issues to experience more depressive and anxiety symptoms.

Furthermore, participants with visual complaints are also more likely to report more depressive and anxiety symptoms than participants without vision problems. These results are in line with previous studies arguing that people with visual or EF deficits also often experience anxiety or depression (Ahern & Semkovska, 2017; Bernabei et al., 2011; Binder et al., 2020; Demetriou et al., 2021; Kempen & Zijlstra, 2014; Snyder et al., 2019).

Contrary to my hypothesis, the strength of the relationship between executive function deficits and depressive and anxiety symptoms, however, does not change with differing numbers of experienced visual complaints. Thus, no evidence was found which would indicate that participants who experience executive function difficulties are more likely to have depressive and anxiety symptoms if they also experience more visual complaints.

Limitations

Several limitations of the present report need to be addressed. One main limitation is that the study was not designed to answer the report's research question. Unlike other studies that have looked at links between EF deficits and anxiety or depression as well as visual complaints and anxiety or depression, the dataset used in this report was from a non-clinical sample. Most of the participants reported no or only very few symptoms. It would have been more appropriate to use a sample reporting at least several depression and anxiety symptoms to facilitate the analysis.

Another limitation of the sample is that the participants were recruited by convenience. Without random sampling, it cannot be excluded that the current sample is biased. There might have been a certain common factor that the participants share, that led them to volunteer to participate in the study. Furthermore, the fact that the sample is a convenience sample decreases external validity. The participants due to not being chosen randomly, are most likely not fully representative of the Dutch healthy population over 18 years. Therefore, the results of this report cannot be generalized to the general adult healthy Dutch population.

A further shortcoming of the study is that the self-report measures only allow for correlational inference. Additionally, the study has a cross-sectional design instead of being longitudinal. Therefore, no directionality of the effect can be studied and established. Nonetheless, the directionality between EF deficits and anxiety and depression symptoms is very controversial, and previous studies have also not been able to assess the direction of the effect (Snyder et al., 2019).

An additional weakness of the present report is the missing data. The missing data was not linked to the observed data. Therefore, it is not possible to estimate the reason why these values were missing, and it is not possible to estimate the potential bias of the missing data. This complicates the interpretation of the results, as we cannot exclude that the missing values were not missing at random and do not know on what factor our available data is biased. It is, however, possible that the missing values were related to other variables from the original dataset, which were not included in this report.

The construct validity of some variables is quite low. For instance, it is difficult to find information on the different validities of the BRIEF questionnaire. Thus, it is not possible to know how much the questionnaire correlates with similar questionnaires and whether it differs from dissimilar self-report measures. The reliability, however, seems to be quite high with a Cronbach's alpha of 0.80 (Roth et al., 2014). For the DASS, on the other hand, more information was available. Convergent validity was reported to be quite high (r = .66 - .78) as well as reliability with a Cronbach's alpha of 0.93 (Crawford & Henry, 2003; Henry & Crawford, 2005). Divergent validity, however, was low as the correlation between scales with different constructs still showed a moderate correlation instead of being weakly correlated (Crawford & Henry, 2003). Nevertheless, it has to be considered that depression and anxiety, which were compared to examine divergent validity, often cooccur (Almeida et al., 2012). This could have increased the correlation between the depression and anxiety scales. In the current report, I looked at the total score of the DASS in which the depression and anxiety scale results are already summed up. Thus, discriminating between anxiety and depression was not relevant for the present analysis in any case. However, more extensive information on the divergent validity of the DASS such as how it differentiates between mental disorders that are not included in the questionnaire is missing. This missing information reduces the divergent validity of the DASS and limits the validity of the presented results. The SVC convergent and divergent validities were calculated in the original dataset of which a subsample was used in the present report. These validities were reported to be high, and reliability was also good with a Cronbach's alpha of 0.85 in the original study. Considering all the above points, I would evaluate the construct validity of the BRIEF and DASS as low, but of the SVC as high. For the control variables in general it can be said that they were measured by directly asking the participants their age, sex, or whether they have been to a psychiatrist or neurologist and, thus, their construct validity should be high. For the education level, however, it was not exactly specified which education degrees or years of education were included in which category. Therefore, the construct validity of the education level variable is quite low. In regard to the variables showing a low construct validity, extra caution in the interpretation of the analysis results in which these were included is required.

A strength of the sample, on the other hand, is that the sample with 400 participants was quite large. This increases the robustness as well as the power of the analytic methods.

The statistical conclusion validity of my results is limited by several factors. Due to the violations of normality, homoscedasticity, and linearity for the multiple regression model, I decided to dichotomize my outcome variable and conduct a logistic regression analysis. To have a balance in the two levels of the outcome variable I decided to include scores from 0 to 3 in one level and 4 to 63 in the other. This decision was influenced more by practicality and not by theoretical reasoning. Information might have been lost due to dichotomizing a continuous variable, especially when choosing the inclusion criteria for the levels based on practicality instead of theoretical background. Other assumptions were less of an issue. Multicollinearity, for instance, was quite high but it was

greatly reduced by centering the predictor variables. Additionally, no influential observations were detected. The significant p-values were much lower than the set significant level of alpha equal to 0.05, which implies that the obtained results are quite unlikely under the null. This gives more weight to the results.

In future studies, these limitations could be addressed by using a clinical sample or a sample with people at risk of experiencing more depression and anxiety symptoms. Of course, this would then again decrease generalizability. However, follow-up studies could examine to what extent the found effects can be generalized to other populations. Additionally, the participants should be chosen at random and then asked to participate instead of including volunteers in the sample. The directionality between the relationship between executive function deficits and depressive and anxiety symptoms as well as the link between visual complaints and depressive and anxiety symptoms should be further assessed. This could be achieved by a longitudinal design in which randomly chosen children or teenagers are studied over a long period. Then it could be established whether executive function difficulties respectively visual complaints or depression and anxiety symptoms appear first. Finally, it is crucial to prevent missing data and to examine what the common factor in the missing data from the current report was. To accomplish this the original dataset could be analyzed to assess whether the missing data is correlated with another reported variable.

Conclusion

In conclusion, the results did not support my hypothesis that visual complaints moderate the relationship between executive function deficits and the amount of anxiety and depression symptoms. Nonetheless, experiencing visual complaints, as well as EF deficits on their own were found to increase the likelihood of having more anxiety and depressive symptoms in the dataset used in this report. The directionality of these associations, however, remains unclear. The results, indicating that EF deficits, as well as visual complaints, are related to depression and anxiety symptoms are in line with previous research (Ahern & Semkovska, 2017; Bernabei et al., 2011; Binder et al., 2020; Demetriou et al., 2021; Kempen & Zijlstra, 2014; Snyder et al., 2019). This report is, to my knowledge, the first to examine visual complaints as a possible moderator in the relationship between EF deficits and anxiety and depression. Future studies could address the limitations of this report as outlined in the previous paragraph.

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