

Analysis Plan: Application of a novel paired comparison tool to explore emotion preferences in adults and adolescents with and without depression.

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1. Introduction.

Our experience of emotion and interpretation of emotional states are fundamental aspects of the human experience. From an evolutionary perspective, emotions serve as adaptive responses to the environment when activated in contextually appropriate circumstances and play an important role for our survival. For instance, in the face of a threat, fear or anger could be activated which physiologically prepare the organism for flight or fight. Whilst in everyday life, emotions facilitate decision making.

Subjective well-being has been operationalised as a combination of the frequency of positive and negative emotions, or affect, and life satisfaction (Diener et al., 1999), with positive and negative affect being negatively correlated with one another and contributing opposite effects to subjective well-being (Bussèri, 2018). Aversive emotions such as anger and sadness have been associated with negative health outcomes and reduced psychosocial functioning (Kawachi & Berkman, 2001). However, notably, these associations are affected by individuals' valuations of negative emotions (Luong et al., 2016), and our appraisals of and responses to emotions can alter their trajectories. When emotions are activated in an overgeneralised, context insensitive manner and interfere with daily functioning, such as in affective disorders, they are considered maladaptive. For instance, major depressive disorder (MDD) is chiefly characterised by protracted sadness (negative affect) and the diminished capacity to experience pleasure (i.e. anhedonia) (DSM-V, 2013).

It is sometimes assumed that humans are hedonically motivated, i.e., are motivated to act based on the pursuit of pleasure and avoidance of pain, thus are driven to attain or maintain positive affective states and diminish or eliminate negative affective states. Indeed, this is often the perceived goal in adaptive emotion regulation, which refers to the process of modulating, either consciously or unconsciously, one's emotional reactions to pursue individual goals or desired affective states (Thompson, 1994). How individuals modulate their emotions depends on their emotional preferences (how they value different emotions and how they want to feel) in addition to which emotion regulation strategies are habitual (Vanderlind et al., 2020). While pro-hedonic motivations for emotion and mood regulation are predominant amongst healthy individuals, humans are not solely driven to maximise positive affect, as demonstrated through studies examining contra-hedonic tendencies in emotion regulation (Riediger et al., 2009; Riediger & Luong, 2016) and mood homeostasis (Taquet et al., 2016, 2020). Two main themes arise in research examining the contexts in which people prefer negative emotions. The first being the instrumental approach to emotion (preferring emotions that are useful), and the second that negative emotion may be accompanied by positive emotions (as in mixed affect), or in some other way perceived to have a positive side. Examples of the latter include listening to sad music (Millgram et al., 2015), or watching horror films (Andrade & Cohen, 2007), when they induce both pleasant and unpleasant emotions.

Contrary to a purely hedonic motivation, the hedonic flexibility principle posits that individuals have multiple, and at times competing, short- and long-term goals, and affect helps guide the pursuit of these rewards and goals. Recent work examining how the valence of current affect predicts subsequent engagement in various activities found support for this theory in that individuals were more likely to

engage in mood boosting activities (e.g. sports) when experiencing low mood, and more likely to engage in useful albeit mood-decreasing activities (e.g. chores) when experiencing positive mood (Taquet et al., 2016, 2020). The degree to which affect and subsequent activity aligned in this way was operationalised in a measure of an individual's level of mood homeostasis. Notably, in those with a history of depression or low mood this relationship was weaker or non-significant, indicating that mood homeostasis is disrupted in affective disorders like depression (Taquet et al., 2020).

Contra-hedonic motivations, i.e. seeking to enhance or maintain 'negative' affect or dampen 'positive' affect can serve utilitarian function when negative emotions are more instrumental to goal attainment or social cohesion compared with positive emotions. For instance, experimentally it was demonstrated that when presented with in a situation perceived as requiring confrontation, participants preferred to induce anger rather than happiness, and viewed this emotion to be useful in subsequent negotiation (Kim et al., 2015; Tamir et al., 2008; Tamir & Ford, 2009, 2012). Moreover, when participants were administered a paired-comparison questionnaire on emotions, positively valenced emotions were preferred over negatively valenced emotions when presented acontextually, however negative emotions were preferred when presented in a context congruent with the negative emotion (Västfjäll & Gärling, 2006).

The degree to which individuals tend towards maintaining or amplifying negative emotions, both in general and context dependently, depends on psychological well-being and vary with age.

Adolescence is a period of significant biological, psychosocial and cognitive development (Steinberg, 2005), during this time there is a particularly salient focus on being authentic and discovering one's identity (Harter, 2002; Thomaes et al., 2017). This developmental stage is marked by heightened intensity of emotions, particularly greater negative emotionality (Larson et al., 2002), and it is estimated that 48% of mental health disorders begin by the age of 18 (Solmi et al., 2022). There is also evidence that adolescents experience greater contra-hedonic tendencies compared with adults. Riediger et al employed experience-sampling to examine whether people wanted to maintain, dampen or amplify their mood (Riediger et al., 2009). Across age (14-86 years; $n = 378$), the majority of the time individuals reported pro-hedonic motivations. However, the prevalence of contra-hedonic motivation was highest in adolescents, with adolescents reporting contra-hedonic tendencies 15% of the time. Interestingly, adolescents also reported experiencing mixed affect more frequently, which partially explained their greater contra-hedonic tendency (Riediger et al., 2009).

Empirically, Riediger et al found that those with lower levels of well-being exhibited greater levels of contra-hedonic motivation compared with those with high well-being. In depression mood homeostasis is disrupted, while contra-hedonic tendencies and maladaptive emotion regulation strategies are prevalent. For instance, depressive symptomatology is associated with increased dampening of positive emotions, such that negative thoughts are engaged with to reduce the intensity or duration of positive affect (Feldman et al., 2008). A further example of this can be seen in the increased engagement in ruminative thinking in depression (McLaughlin & Nolen-Hoeksema, 2011; Spasojević & Alloy, 2001), which refers to repetitive, self-focused thought regarding one's feelings and problems and the consequences and is considered a maladaptive emotion regulation strategy. Despite rumination being an aversive, negative experience, which has been shown to enhance or prolong negative affective states (Watkins & Baracaia, 2001), empirical evidence indicates that even when depressed individuals do not demonstrate diminished capacity to implement more adaptive emotion regulation responses, such as cognitive appraisal, they are more likely to engage in rumination (Liu & Thompson, 2017). While rumination is often an automatic or compulsive repetitive process in depression, at the meta-cognitive level individuals endorse the belief that rumination is valuable in that it enhances understanding and insight into their past and present issues (Watkins & Baracaia, 2001). Thus, while people with depression may be aware that rumination amplifies or prolongs negative affect, it is perceived as useful nonetheless.

Whilst there has been substantial research into how people regulate their emotions and recent research has explored the motivations preceding emotion regulation, less research has examined how people feel about, value, and view their emotions.

Although experiencing relatively high levels of positive affect compared to negative affect is conducive to well-being (Bussieri, 2018), individuals' preferences or biases towards or against particular emotions can impact their well-being in seemingly paradoxical ways. For instance, highly valuing happiness has been associated with experiencing less happiness and heightened disappointment (Mauss et al., 2011). Moreover, Humphrey et al. found that the relationship between highly valuing happiness and lower well-being was partially mediated by an aversion to feeling negative emotions (Humphrey et al., 2022).

The present study:

1.1 Primary Aim

To use a novel paired comparison tool to explore how people feel about and value emotions, particularly sadness, and how this varies by age and depression-status. We will examine emotion preference rankings descriptively and conduct exploratory analysis to examine how emotion preferences differ between groups. We will also test the following hypotheses described below.

1.2 Primary Hypotheses

Intraindividual:

Given that evidence suggests people in part prefer emotions that are useful over pleasant, and that negative emotions are preferred when they are contextually appropriate, we hypothesise that:

1. Across subjects, the more nuanced items such as those endorsing the utility of emotions will be most preferred (i.e. items 2,4,7,8,9).
2. Across subjects, the absolute items 5, 12 and 13 (i.e., 'Anger is always good', 'Anger is never good and 'It is never good to feel low') will be infrequently preferred.

Interindividual, between-group:

Depressed subjects vs healthy controls:

Given that in depression there is evidence that individuals value perceived insight gained from aversive affective states, we hypothesise that:

3. Depressed subjects will rank 'I have learned a lot about myself by being sad' and 'When I feel low, I can see things more clearly' higher than non-depressed subjects.

Adolescents vs adults:

As adolescence is a time of identity exploration and formation and heightened contra-hedonic tendencies, whereas adults may be able to better understand the necessity of context-dependent emotion regulation and expression, we hypothesised that:

4. Adolescents will rank 'I am always trying to be myself, even if this makes me feel low' higher than adults.

1.3 Secondary Hypothesis

Relationship between reaction time and rank distance:

5. The greater the distance in rank between two items, the shorter the reaction time for the item pair will be i.e., rank distance will be negatively correlated with reaction time.

2. Methods

2.1 Study Design

In this observational, cross-sectional study, participants completed an online survey at a single time point. After providing informed consent, participants provided socio-demographic information and completed several questionnaires.

2.2 Ethical approval and Funding

The study was conducted in accordance with international guidance on scientific experimentation with humans and received ethical approval from the National Institutes of Health Office of Human Research Subject Protection Protocol #P194594 and Institutional Review Board Protocol ethics committee 0037. Funding was provided by the NIH Intramural Programme for the Grant: Characterisation and Treatment of Adolescent Depression, NIH Grant Number ZIA MH002957-03. Funding for the present analysis was provided by the Medical Research Council (MRC): MR/W006774/1.

2.3 Knowledge of existing data

AS and DN have had full access to the data and conducted descriptive statistics on a subset of the data. No inferential statistical analysis has been conducted or published on these data. KT did not have access to the data prior to the publishing of this analysis plan.

2.4 Recruitment & Participants

Study advertisement: Adolescent participants in the ongoing National Institute of Mental Health Characterization and Treatment of Adolescent Depression (CAT-D) study were offered the chance to complete the online task. Adult participants were recruited through CloudResearch's participant panel. **Adult Sample:** We targeted collection of data from individuals each with and without depression based on response to "Do you suffer from depression?" which is part of the set of questions CloudResearch collects from all members of their participant panel. We targeted $n = 100$ participants with and $n = 100$ without depression for the survey.

Inclusion and exclusion criteria: Adult Sample: Members of CloudResearch's participant panel 18 years or older and had no neurological disorders. Adolescent sample: aged 11 – 17 years old, for inclusion/exclusion criteria of CAT-D study see

<https://acamh.onlinelibrary.wiley.com/doi/full/10.1111/jcpp.13547>.

The total numbers of participants per group is presented in Table 1. Participants scoring ≥ 16 on the Center for Epidemiologic Studies Depression Scale (CES-D) were categorised as depressed.

Table 1. Sample sizes per group.

	Adult (n)	Adolescent (n)
Health control	100	36
Depressed subjects	100	38
Total	200	74

2.5 Variables

Age (in years)

Gender (male 0; female 1)

Center for Epidemiologic Studies Depression Scale (CES-D)

Mood and Feelings Questionnaire (MFQ)

Emotion Preferences

Emotion preference items. This scale was devised by AS and DN. The following 14 items (Table 2) were presented to participants in a pairwise manner, i.e., each item was presented with every other item in pairs. For each pair, participants were required to select which item they agreed with more, creating a binary outcome for each item (win 1, lose 0). Reaction times were recorded for each choice participants made. Number of paired comparisons is calculated as $n*(n-1)/2 = 91$; where n =number of items (14).

Table 2. Emotion Preferences Tool

Item Number	Emotion Preference Items
1	I never want to be sad again.
2	I feel that occasional sadness is important.
3	I enjoy feeling melancholy sometimes.
4	It is not always bad to feel low.
5	It is never good to feel low.
6	When I feel low I can see things more clearly.
7	Feeling sad sometimes is part of normal life
8	I have learnt a lot about myself by being happy.
9	I have learnt a lot about myself by being sad.
10	How one feels is not the most important thing.
11	I am always trying to be myself, even if this makes me feel low.
12	Feeling anger is always good.
13	Feeling anger is never good.
14	Anger can be important in life.

Center for Epidemiologic Studies Depression Scale (CES-D)

The CES-D is a 20-item self-report questionnaire which measures depressive symptomatology over the past week (Radloff, 1977). Each item has four possible responses which are scored on a scale of 0 to 3: Rarely or none of the time (less than 1 day); Some or a little of the time (1-2 days); Occasionally or a moderate amount of the time (3-4 days); Most or all of the time (5-7 days). Total scores range from 0 to 60, with higher scores corresponding to greater severity of depression. A score of ≥ 16 were indicates significant levels of depression.

2.6 Statistical Analyses

Assumptions for each statistical test proposed will first be checked, and alternative or additional tests will be conducted if necessary. If assumptions are not met for proposed z tests, binomial tests will be conducted instead. An alpha value of 0.05 will be used and p-values will be adjusted to correct for multiple comparisons as described below. We do not restrict ourselves to the analyses below, and may conduct further exploratory analyses.

Participant characteristics

Participant characteristics will be compared across groups.

Intraindividual Item Ranking

An item ranking will be calculated for each individual based on the number of wins per item.

Descriptive Statistics: Emotion Preference Ranking by Group

Group rankings will be calculated based on the average number of wins per paired comparison and explored descriptively.

Statistical Ranking of Emotion Preferences Across Groups

The total wins for each item will be summed across all paired comparisons and the proportion of wins will be calculated across groups. One proportion z -tests will be conducted for each paired comparison using the proportion of total item wins. For each z-test, the null hypothesis (H_0) will be that the proportion of participants endorsing either item in the pair will not be different from 0.5. The alternative hypothesis (H_A) will be that proportion of total wins per paired item will be different from 0.5.

$$H_0: p_{\text{itemA}} = p_{\text{itemB}} = 0.5$$

$$H_A: p_{\text{itemA}} \neq p_{\text{itemB}} \neq 0.5$$

ItemA and ItemB: items in each paired comparison.

Items will then be ranked from highest to lowest number of significant wins. To account for multiple comparisons, the p-values will be adjusted for false discovery rate (FDR).

Comparing Ranks across groups

Kendall's Tau will be conducted to compare similarity of rankings across i) adolescent depressed subjects and adolescent healthy controls, and ii) adult depressed subjects and adult healthy controls. This will be an exploratory analysis and therefore we will not conduct a power calculation.

Intraindividual differences in Emotion Preference Ranking

To test hypothesis 1, i.e. whether items 2,4,7,8 and 9 were most preferred, we will test whether these items are ranked higher than average (i.e. above rank 7), a single binary outcome will be created per participant based on their individual emotion preference rankings:

Items of interest are all ranked 7 or above = 1

Items of interest are not all ranked 7 or above = 0

A z-test will be conducted on this binary variable to test the following hypotheses:

$H_0: p(\text{itemsX_all_ranked_above_7}) \leq p(\text{itemsX_not_all_ranked_above_7})$;

$H_a: p(\text{itemsX_all_ranked_above_7}) > p(\text{itemsX_not_all_ranked_above_7})$.

Items X = 2, 4, 7, 8 and 9.

To test the hypothesis 2, i.e. whether items 5, 12 and 13 were least preferred, a binary outcome will be created per participant based on their individual emotion preference rankings:

Items of interest are all lower than 7 = 1

Items of interest are not all ranked lower than 7 = 0

A one-proportion z-test will be conducted on this binary variable to test the following hypotheses:

$H_0: p(\text{itemsY_ranked_below_7}) \leq p(\text{itemsY_not_ranked_below_7})$;

$H_a: p(\text{itemsY_ranked_below_7}) > p(\text{itemsY_not_ranked_below_7})$.

Items Y = items 5, 12 and 13.

Testing interindividual differences: Comparing ranked items across groups

Two proportion z -tests will be conducted to test group differences to address hypotheses 3 and 4 described below. To test hypothesis 3, the following items (6 and 9; 'I have learned a lot about myself by being sad' and 'When I feel low, I can see things more clearly') will be compared across depressed subjects and healthy controls, the null and alternative hypotheses are presented below.

$H_0: p(\text{item } Z_D) = p(\text{item } Z_HC)$

$H_a: p(\text{item } Z_D) > p(\text{item } Z_HC)$

Items Z = items 6 and 9, tested individually.

Where group differences are found across depressed vs non-depressed subjects, we will conduct further analyses per age-group to explore a potential interaction with age.

For hypothesis 4, the ranking of the item 'I am always trying to be myself, even if this makes me feel low' (item 11) will be compared across adult and adolescent subjects the null and alternative hypotheses are presented below.

$H_0: p(\text{item11_T}) = p(\text{item11_A})$

$H_a: p(\text{item11_T}) > p(\text{item11_A})$

HC=healthy control; D=depressed; T=teen/adolescent; A=adult.

Where age-group differences are found in the sample, we will conduct further analyses per depression-status group to explore a potential interaction with depression.

Relationship between reaction time (RT) and rank distance:

We will test this secondary outcome by estimating the correlation between RT and the distance between an item pair and expect that rank distance will be negatively correlated with reaction time using Pearson's correlation. RT will be log transformed in order to normalise the data. If data are not normally distributed, Spearman's correlation will be conducted.

Outliers were removed from latency data using median absolute dispersion technique. This outlier removal technique is itself more robust to the presence of outliers and has been recommended for use with latency data (Leys et al., 2013). Using this approach, an outlier is defined as being greater than three scaled absolute deviations from the median [$\text{median}(|Y_i - \text{median}(Y)|)$]. Outliers were removed from the raw latency data for each subject in each environment. Latencies were then log transformed for use in linear regression models.

Power analyses.

Power analyses were conducted to calculate the required sample sizes to test the primary hypotheses using pwr package in R version 4.2.1; the code is presented in Table 3. We conducted power analysis using pwr.p.test function from pwr package to determine the sample size required to obtain 80% power to identify a 15% difference in proportions (i.e. a small-medium effect size; arcsine transformation was employed to transform this into a Cohen's h (h) effect size of 0.3978). A small-medium effect size was chosen to strike a balance between power and required sample size. An alpha level of 0.05 was used and adjusted for 91 paired comparisons using Bonferroni correction (i.e. 0.05/91). Bonferroni correction was utilised in the power analysis for ease of calculation, however, as previously stated, FDR will be used in the statistical analyses.

```
pwr.p.test(h=(asin(sqrt(0.15))),power=0.8,sig.level=(0.05/91),alternative="two.sided")
```

This resulted in a required sample size of $n=117$ to create an overall ranking of items across groups based on number of statistically significant wins per item pair.

To test group-differences in the proportion of wins for specific items, sample size was calculated using the pwr.2p.test function from the pwr package with the following parameters: power = 80%; alpha = 0.05; $h = 0.3978$:

```
pwr.2p.test(h = (asin(sqrt(0.15))), n = NULL, sig.level = 0.05, power = 0.8, alternative = "two.sided")
```

This estimated a required sample size of $n=100$.

Given the number of adolescents ($n=74$) in the present study was below 100, a second analysis was conducted to ascertain the power for testing differences in proportions between the actual sample sizes of adults ($n=200$) vs adolescents ($n=74$). For this we used the function pwr.2p2n.test with the same parameters for effect size and alpha:

```
pwr.2p2n.test(n1=200, n2=74, sig.level=0.05,power=NULL, h=(asin(sqrt(0.15))))
```

This provided an estimated power of 83%.

Power calculation for secondary hypotheses of RT with rank distance.

We show below using power simulations that we are well powered to detect correlations that are $r \geq 0.3$ (criterion 90% of correlation coefficients will be $r \geq 0.25$).

We simulated data using the rnorm_multi function and conducted power analyses on this data. For rank distance we modelled the data on an average of 7 and standard deviation 3; for RT we modelled the data on an average of 300ms and standard deviation of 100ms. These variables were simulated to have a correlation coefficient of 0.3. Alpha was set to 0.05, and cut off criterion for the correlation coefficient was set to 0.25. Using these parameters, we tested sample sizes from 10 – 100, in intervals of 10 (i.e. 10 different sample sizes total). For each sample size, 500 simulations were run. The power was determined by calculating the proportion of correlations which met the criteria of $r > 0.25$ and $p < 0.05$. Power was plotted against sample size to determine what sample size was required. The R code for these simulations are presented in Appendix 1.

Results from these analyses indicated that to obtain 90% power, a sample size of >38 participants is required (see Figure 1).

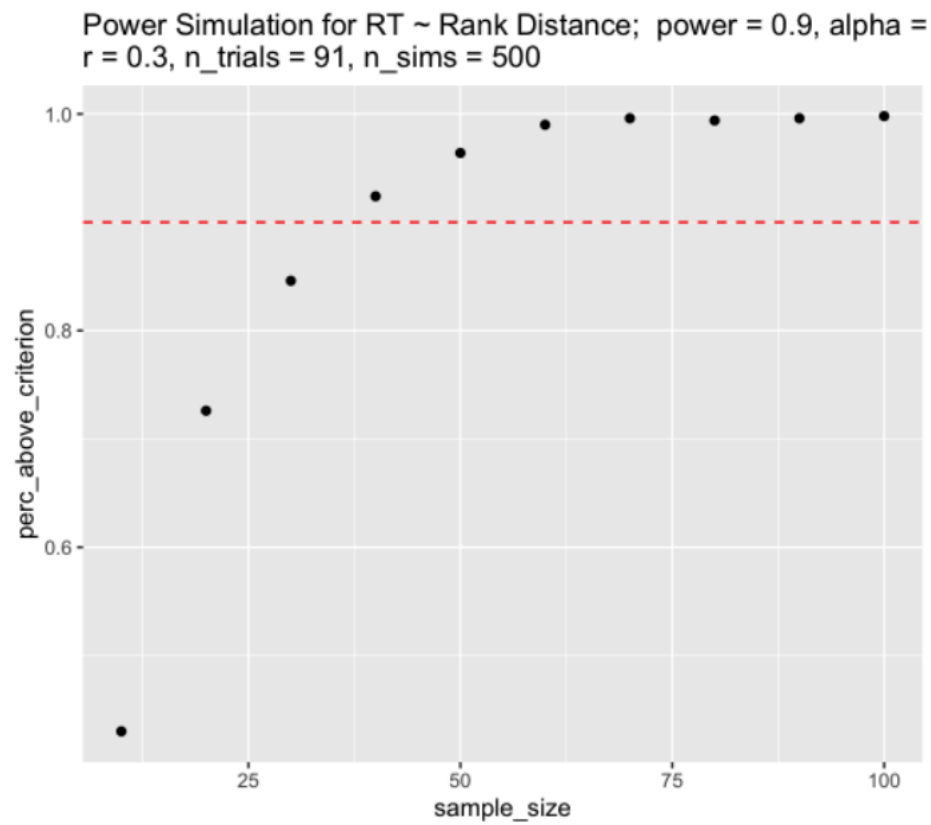


Figure 1. Results from power calculation for correlating Reaction time (RT) with rank distance using simulated data. Perc_above_criterion represents power, with 90% power indicated via the dashed line.

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Appendix 1. R Script for power calculation for secondary outcome of RT with rank distance.

```
## get per individual correlations,

library(faux)
library(tidyverse)

within_indiv_cor <- function(sample, correlation, avg_1, avg_2, sd_1, sd_2, n_trials,
coef_criterion)
{
  vars <- 2 # the number of variables
  df_list <- list()

  for (i in 1:sample){
    df_list[[i]] <- rnorm_multi(n = n_trials, # the faux function for mvn norms; alter to add two
variables with different means etc
      mu = c(avg_1, avg_2),
      sd = c(sd_1, sd_2),
      r = c(correlation),
      varnames = paste0("T_", seq(1:vars)),
      empirical = FALSE)

  }

  # then simply get correlation for each row

  var_with_correlations <- 0 #an empty vector to put the correlations in
  var_with_p <- 0 # an empty vector to put the p-values of each correlation in. We are not
using these, but you can
  # check them. They are the per-individual p-value and are not affected by sample size (but
are by trial number)

  # run a loop for each element of the list to extract correlations and p-values (remember p-
values are optional here)
  for (i in 1: length(df_list)){

    var_with_correlations[i] <- cor.test(df_list[[i]]$T_1,df_list[[i]]$T_2)$estimate # this is the
correlation estimate
    var_with_p[i] <- cor.test(df_list[[i]]$T_1,df_list[[i]]$T_2)$p.value # this is the p-value
estimate (optional)

  }
  df_cors_ps <- data.frame(corrs=var_with_correlations, ps = var_with_p)

  # here comes the one sided test and the p-value that we are going to use
  p_from_t_test <- t.test(var_with_correlations, mu = coef_criterion, alternative = "greater")
  # whether the average across all subjects is above .35
  # here you extract the p-value
```

```

p_from_t_test <- p_from_t_test$p.value # here you extract the p-value from the one-sided
test.
# what you get out is the p-value from that one-sided t-test
return( p_from_t_test )
}

```

```

## here you get for each sample size the proportion of p-values above criterion (fine to use
0.05)
p_values_sample <- list()
perc_p_values_above_p_criterion <- 0

```

```

sample_sizes <- seq(10, 100, by = 10 )
n_sims <- 500
correlation_level = 0.3
mean_level_1 = 7
mean_level_2 = 300
sd_level_1 = 3
sd_level_2 = 100
trial_number = 91
coefficient_criterion = 0.25

```

```

p_criterion <- 0.05 # no reason to correct

```

```

for (i in 1: length(sample_sizes)){

```

```

  p_values_sample [[i]] <- replicate(n_sims,within_indiv_cor(sample_sizes [i],
correlation_level,
                                mean_level_1, mean_level_2,
                                sd_level_1, sd_level_2,
                                trial_number, coefficient_criterion))
  perc_p_values_above_p_criterion [i]<- sum( p_values_sample [[i]] <
p_criterion)/length(p_values_sample [[i]])
}

```

```

perc_p_values_above_p_criterion

```

```

## now plot

```

```

power_level <- .9 # for 90% power

```

```

# create the necessary dataframe
df_for_plot <- data.frame(perc_above_criterion = perc_p_values_above_p_criterion,
sample_size = sample_sizes)

```

```

# prepared the title

```

```

title_1 <- paste0("Power Simulation for RT ~ Rank Distance; ", " power = ", power_level,
", alpha = ",p_criterion)

```

```

title_2 <- paste0("r = ", correlation_level,
  ", n_trials = ", trial_number,
  ", n_sims = ", n_sims)

# now create the actual plot
df_for_plot %>%
  ggplot(aes(x = sample_size, y = perc_above_criterion))+
  geom_point()+
  geom_hline(yintercept = 0.9, colour = "red", linetype = "dashed") +
  ggtitle(paste0(title_1, "\n", title_2))

```