The n-back Test

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Contents

1 Introduction

In 1958, Wayne Kirchner invented the n-back test [3]. The n-back test is a visuospatial task that has been shown to improve working memory and attentional skills [2]. The basic mechanisms of the test involve the presentation of continuous stimulis in terms of letters or pictures – for every stimulus presented, the participant has to indicate whether it matches a stimulus that was presented n stimuli ago [5]. There are different types of n-back tests known as loads: 3-back test, 2-back test and 1-back test [4].

1.1 Important Note

During compilation from the .tex file, if 'unresolved citations' encountered after repeated compiling with LaTeX, compile with bibtex. (latex,latex,latex,bibtex,latex,latex works reliably)

2 Hypothesis

Our hypothesis was that participants would have a more challenging time remembering things initially which would be reflected in a longer reaction time to congruent stimulis in the 2-back test compared to the reaction time of a 1-back test. However, as n-back tests are shown to improve working and short term memory [6], we expect participants to get better at remembering, reflected in shorter reaction times in responding to congruent stimulis.

3 Materials/Methods

3.1 Inline usage

3.1.1 R code

Our results are not particularly well suited for demonstrating the capabilities of org-mode. The following block pulls in normative data from [7] and stores it in the **tables** session

```
## install.packages('dplyr')
## install.packages('ggplot2')
## install.packages('tidyr')
library('dplyr')
library('tidyr')

d <- read.csv("./dataFromPaper/csvfpsyg-06-01544.csv")
tbl_df(d)
oneback<-slice(d,11:12)
twoback<-slice(d,18:19)
threeback<-slice(d,25:26)

mean_sd <- tbl_df(bind_rows(oneback,twoback,threeback))
rename(mean_sd,"Var"=X)
mMeanSD <- tbl_df(select(mean_sd,X:X.8,-X.2))
fMeanSD <- tbl_df(select(mean_sd,X:X.1,Girls:X.14))
mMeanSD
```

Org-mode block as a function to rename columns prior to plotting Note: Glitch wherein specifying header ":colnames yes" replaces the first row of table

```
newColNames <- c("n-back","M_or_SD","7","8","9","10","11","12","13")
names(df) <- newColNames
df
```

4 Results

4.1 Python Code

This code adds headers back into the data

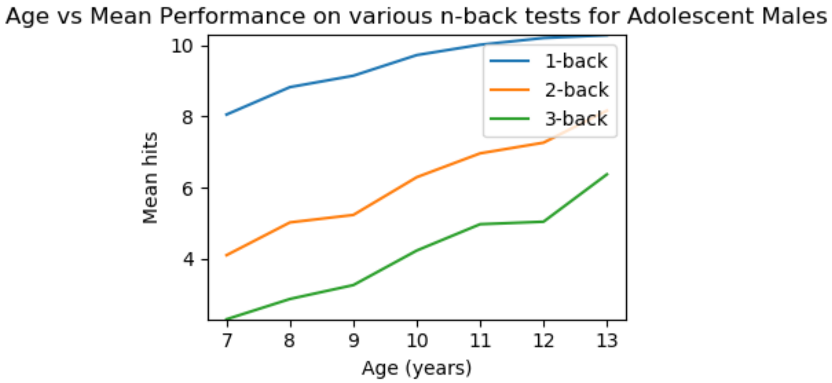
```
import numpy as np
import pandas as pd
dArr = np.array(data)
headers = ["n-back","statistic"]
[headers.append(i) for i in range(7,14)]
headers = np.array(headers)
dArr = np.vstack((headers,dArr))

dArr
```

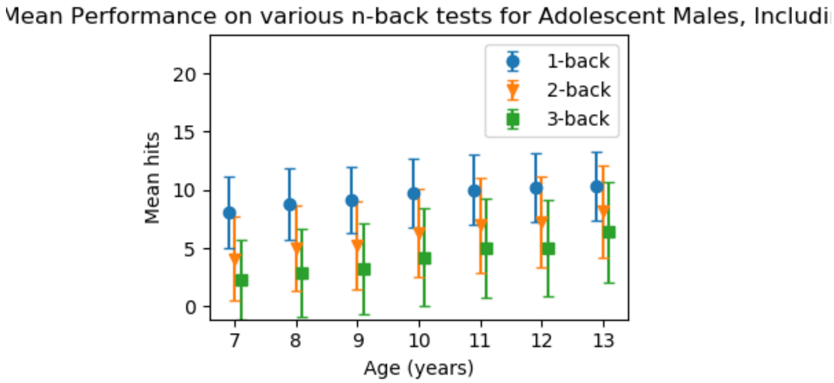
4.2 2 plots

Here is a plot of how improvement on various n-backs improves with age

```
import matplotlib
matplotlib.use('Agg')
import matplotlib.pyplot as plt
data=np.array(data)
datafloat=data[0:,2:].astype(np.float32)
ages=datafloat[0,:]
plt.cla()
plt.clf()
plt.plot(ages,datafloat[1,:],label=data[1,0])
plt.plot(ages,datafloat[3,:],label=data[3,0])
plt.plot(ages,datafloat[5,:],label=data[5,0])
plt.title(label="Age vs Mean Performance on various n-back tests for Adolescent Males")
plt.ylim(np.min(datafloat[5,:]),np.max(datafloat[1,:]))
plt.xlabel("Age (years)")
plt.ylabel("Mean hits")
plt.legend()
plt.savefig('./pyplot1.png')
'./pyplot1.png'
```



```
import matplotlib
matplotlib.use('Agg')
import matplotlib.pyplot as plt
data=np.array(data)
datafloat=data[0:,2:].astype(np.float32)
ages=datafloat[0,:]
plt.cla()
plt.clf()
fig=plt.figure(figsize=(6,3))
plt.errorbar(ages-0.1,datafloat[1,:],yerr=datafloat[2,:],linestyle='None',fmt='o',capsize=3,
plt.errorbar(ages,datafloat[3,:],yerr=datafloat[4,:],linestyle='None',fmt='v',capsize=3,labe
plt.errorbar(ages+0.1,datafloat[5,:],yerr=datafloat[6,:],linestyle='None',fmt='s',capsize=3,
plt.title(label="Age vs Mean Performance on various n-back tests for Adolescent Males, Inclu
plt.ylim((datafloat[5,0]-datafloat[6,0]),(datafloat[0,6]+datafloat[1,6]))
plt.xlabel("Age (years)")
plt.ylabel("Mean hits")
plt.legend()
fig.tight_layout()
plt.savefig('./pyplot2.png')
'./pyplot2.png'
```



5 Discussion

Our experiment was done with the hypothesis that the reaction time to stimuli in a 1-Back test would be shorter than the reaction time to stimuli in a 2-Back test. This was based off of the fact that there is one extra letter presented between letter stimuli to remember during 2-Back tests. This test is a working memory task, but it could also potentially be used to test the recency effect, which has been shown to be eliminated when another stimulus is presented. [1]

6 Bibliography

References

[1] Ronald L. Cohen. The effects of interference tasks on recency in the free recall of action events. *Psychological research*, 51(4):176–180, 1989.

[2] Roberto Colom, Francisco J. Román, Francisco J. Abad, Pei Chun Shih, Jesús Privado, Manuel Froufe, Sergio Escorial, Kenia Martínez, Miguel Burgaleta, M.A. Quiroga, Sherif Karama, Richard J. Haier, Paul M. Thompson, and Susanne M. Jaeggi. Adaptive n-back training does not improve fluid intelligence at the construct level: Gains on individual tests suggest that training may enhance visuospatial processing. *Intelligence*, 41(5):712 – 727, 2013.

[3] Carina Coulacoglou and Donald H. Saklofske. Chapter 5 - executive function, theory of mind, and adaptive behavior. In Carina Coulacoglou and Donald H. Saklofske, editors, *Psychometrics and Psychological Assessment*, pages 91 – 130. Academic Press, San Diego, 2017.

[4] Joan Forns Guzman, Mikel Esnaola, Mónica López-Vicente, Elisabet Suades González, Mar Alvarez-Pedrerol, Jordi Julvez, James Grellier, Nuria

Sebastian Galles, and Jordi Sunyer. The n-back test and the attentional network task as measures of child neuropsychological development in epidemiological studies. *Neuropsychology*, 28, 05 2014.

[5] Michael Kane and Andrew Conway. The invention of n-back: An extremely brief history. *The Winnower*, 06 2016.

[6] Umberto León-Domínguez, Juan Francisco Martín-Rodríguez, and José León-Carrión. Executive n-back tasks for the neuropsychological assessment of working memory. *Behavioural Brain Research*, 292:167 – 173, 2015.

[7] Santiago Pelegrina, M. Teresa Lechuga, Juan A. Garcia-Madruga, M. Rosa Elosua, Pedro Macizo, Manuel Careiras, Luis J Fuentes, and M Teresa Bajo. Normal data on the n-back task for children and young adolescents. *Frontiers in Psychology*, 10 2015.

7 Appendix

7.1 Python Code for n-back test

```
from psychopy import visual, event, core
import pandas as pd
import random
import time as systime

#########
# setup #
#############################

#############
# Make lists / define functions #
#############


def makeMatches(in_list, trials=5,
                threshold=0, n_back=2,
                keep_list_stats=True, verbose=False):
    '''Creates the matches in a given list.if a random number is greater than threshold,
    then match the letters at positions [idx] and [idx-n_back]
    in_list: list of letters, strings, etc
    trials: how many trials to run
    threshold: type(float) in range(0,1)ld
    keep_stats: Bool: will output a list with information on
    the matches (position, character) and their frequency
    verbose: Bool: prints information about the lists for immediate viewing
    '''
    # done this way to avoid changing original list, confirm necessity?
    out_list = [i for i in in_list]
    list_stats = []  # list holding the character and positions it was matched at
    num_matches = 0
    for idx, char in enumerate(in_list):
        if idx > 1:
            if (random.random() > threshold):
                out_list[idx] = in_list[idx-n_back]
                list_stats.append([(idx, idx-2), char]
                                  ) if keep_list_stats else None
                num_matches += 1

                real_match_rate = num_matches / (len(in_list) - 2)
                # show _stats or not
                if verbose:  # switch this out of a print statement for final thing so it do
                    print(
                        f"{num_matches} of {len(in_list)-2} possible matches: {real_match_ra
                    print(f"in_list\n", in_list, "\nmatched list\n", out_list)
                else:
                    pass

                if keep_list_stats:
                    list_stats.insert(0, [(num_matches), "number of matches"])
                    list_stats.insert(0, [(real_match_rate), "actual match rate"])
        return(out_list, list_stats)
    else:
        return(out_list)


#####################
# create trial list #
#####################

n_trials = 15
# need to think of this inverted with how the code is currently written
match_frequency_threshold = 0.5
alphabet = [i for i in "ABCDEFGHIJKLMNOPQRSTUVWXYZ"]
initial_letters = [random.choice(alphabet) for i in range(n_trials)]

trial_list = makeMatches(initial_letters, trials=n_trials,
                         threshold=match_frequency_threshold, keep_list_stats=False)
ptt = 1.2
# ptt is the amount of time between trials, stands for "per time trial"

######################
```

```
# Window setup below #
######################
mywin = visual.Window(fullscr=True, screen=0, allowGUI=False, allowStencil=False,
                      monitor='testMonitor', color=[0, 0, 0], colorSpace='rgb')

clock = core.Clock()  # this is a clock

press_times = []  # List records the data


##############################

intro = True

if intro:
    # TODO  Find out how to display the last sentence in text_string
    text_string = f"This is an N-Back task.  This task is a test of working memory.  You wil
    textList = text_string.split("  ")
    for msg in textList:
        displayMsg = visual.TextStim(
            mywin, text=msg, pos=(0.5, 0))
        mywin.flip()
        displayMsg.draw()
        core.wait(3.5)

    countdownMessage = visual.TextStim(
        mywin, text='The task will begin after this countdown.', pos=(0.5, 0))
    countdownMessage.autoDraw = True
    mywin.flip()
    core.wait(3.5)
    countdownMessage.text = ' '
    mywin.flip()
    core.wait(0.5)



countdownString = "5,4,3,2,1"
countdown = countdownString.split(',')
# ct is the countdown timer

for num in countdown:
    txtDisplay = visual.TextStim(
        mywin, text = num , alignHoriz='left', alignVert='center', pos=(0, 0))
    mywin.flip()
    txtDisplay.draw()
    core.wait(1.0)
```

```
###################
# display letters #
###################

trialTime = core.Clock()

for idx, char in enumerate(trial_list):

    trialLength = core.CountdownTimer()
    keys = event.getKeys(keyList=["space"], timeStamped = trialLength)
    txtDisplay.text = char
    mywin.flip()
    txtDisplay.draw()
    print(keys, trialLength.getTime(), txtDisplay.text)
    press_times.append([keys, trialLength.getTime(), txtDisplay.text])
    core.wait(ptt)
    txtDisplay.text = "+"
    mywin.flip()
    txtDisplay.draw()
    core.wait(ptt)
    trialLength.reset()
    # currently appending in tuple form list_stats = []  # list holding the character and po

endMessage = visual.TextStim(
    mywin, text = ’ ’, pos=(0.5, 0))
endMessage.autoDraw=True
mywin.flip()
core.wait(1.5)
endMessage.text = ’You have completed the N-Back task. Thank you!’
mywin.flip()
core.wait(3.0)

print(press_times)

ts = systime.localtime()
timestamp = str(systime.strftime("Y%yM%mD%dH%HM%MS%S",ts))
datafile = open(f"datafile_{timestamp}.txt", "w+")

################
# writing file #
################
for line in press_times:
    datafile.write(str(line))
    datafile.write("\n")
    datafile.close()

# #not sure needed
# for line in n_list:
#     datafile.write(line,)
#     datafile.write("\n")

# for line in stats:
#     datafile.write(line)
#     datafile.write("\n")
```

7.2 Example data collected from our python code

The output file's name was datafile$_{\text{Y19M12D03H16M01S43.txt}}$

```
[[], -0.004664508000132628, 'D']
[[], -0.004164268000749871, 'Z']
[[], -0.00399026299965044, 'D']
[[], -0.0038331880004989216, 'B']
[[], -0.00503896499867551, 'Q']
[[], -0.003854009999486152, 'B']
[[], -0.0046000490001461, 'O']
[[], -0.004559805000099004, 'C']
[[], -0.003853826001432026, 'O']
[[], -0.004379994001283194, 'G']
[[], -0.0045756989984511165, 'K']
[[], -0.004432972000358859, 'E']
[[], -0.003947705999962636, 'K']
[[], -0.003957068000090658, 'D']
[[], -0.004081728999153711, 'C']
```