

T1 Title: The Interaction Between Working Memory and Inhibition in Measures of Behavioural Regulation

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T3 Date of Preregistration

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T5 Identifier

EINGGSC1

T6 Estimated duration of project

12 months

T7 IRB Status

Ethical approval has been secured from the University of Bristol's School of Psychological Science Human Research Ethics Committee (ref: 2021-0216-181)

T8 Conflict of Interest Statement

None

T9 Keywords

Working Memory; Inhibition; Executive Control; Attention

T10 Data accessibility statement and planned repository

Data access via download; usage of data for all purposes (public use file)

T11 Optional: Code availability

T12 Optional: Standard lab practices

Abstract

A1 Background

Previous studies of executive functioning have tended to use separate tasks to measure working memory and inhibition, increasing the confounding effect of task-specific variance.

A2 Objectives and Research questions

Here we employ two novel tasks that orthogonally manipulate the working memory and inhibitory control demands within each paradigm.

A3 Participants

96 adult participants will be recruited for an online study.

A4 Study method

Participants will be given 4 conditions of a choice reaction time task formed by the crossing of two levels of inhibition with two levels of working memory load. The task involves determining which spatial response location is associated with each stimulus. They will also receive 4 conditions of a selective response task formed by crossing two levels of inhibition with two levels of working memory load. The task involves making 'go' responses to half the stimuli while withholding a response to the other stimuli.

Introduction

I1 Theoretical background

One potential definition of executive control is that it reflects the combination of goal representation in working memory and the inhibition of goal-irrelevant responses. Studies of executive control have therefore attempted to measure each of these constructs (and, often, participants' ability to engage in 'shifting' in addition). However, previous work has tended to use separate tasks to measure working memory and inhibition. On the one hand this increases the confounding effect of task-specific variance, but, on the other, the measures employed are often not process pure (for example, tests of inhibition often have a memory component to them). This is important given the need for accurate assessment of these constructs, and their potential interaction, in conditions such as autism and Attention Deficit Hyperactivity Disorder.

I2 Objectives and Research question(s)

In this study we will employ two novel tasks - one involving pre-potent response inhibition in a choice reaction time task, the other involving behavioural inhibition in a selective response task. In each we orthogonally manipulate the memory load across conditions of the tasks by varying the number of stimulus-response associations that have to be maintained. This allows us to examine main effects of both working memory and inhibitory load, and their interaction. In addition, we will explore the correlations between the inhibition and memory components of our tasks and measures of autistic traits and ADHD-related traits in our participants.

I3 Hypothesis (H1, H2, ...)

H1 - we predict main effects of working memory load and inhibitory load.

H2 - we predict an interaction between working memory load and inhibitory load on the assumption that both functions draw on a common pool of executive control capacity. However, while this theoretical model is plausible, it is not the only model of executive control. It is also the case that an interaction is only expected when executive capacity is exceeded by the combined demands of the task. This may not be the case for all (or indeed any) of our participants depending on the difficulty of the task conditions.

I4 Exploratory research questions (if applicable; E1, E2,)

E1 - we will examine the correlations between the different conditions of each task, and between the corresponding conditions of the two different tasks.

E1a - a question of interest is whether the two tasks tap separable forms of inhibition (i.e., do the inhibitory aspects of a given task correlate across the conditions of that task, but not with the other task and vice versa).

E2 - we will examine the associations between these different measures of task performance and self-reported measures of autistic traits and ADHD traits

E3 - we will explore the effects of trial transitions in the tasks.

Method

M1 Time point of registration

Registration prior to analysis of the data

M2 Proposal: Use of pre-existing data (re-analysis or secondary data analysis)

No

Sampling Procedure and Data Collection.

M3 Sample size, power and precision

This study builds on two previous (yet to be fully analysed) studies that have separately tested each of the two tasks in adult samples of 48 participants (see O1). This study aims to test 96 participants. This provides 95% power to detect a correlation of .36 or above. We will carry out no analysis of data prior to the completion of testing.

M4 Participant recruitment, selection, and compensation

Participants will be recruited through Prolific and will be paid at the standard Prolific rate for an hour's participation.

Participants will all be aged between 18 and 30. Other demographic factors will not be considered a barrier to inclusion or be balanced across the sample.

M5 How will participant drop-out be handled?

The experiment will take place in a single online session. Therefore we anticipate no drop-outs between sessions. If a participant fails to complete the session any partial data they provide will not be included in any analyses. We will seek to replace such an individual with an additional participant.

M6 Masking of participants and researchers

No masking will take place.

M7 Data cleaning and screening

Reaction time outliers in the choice reaction time task will be trimmed using the Median Absolute Deviation (MAD) method described by Leys, Ley, Klein, Bernard, & Licata (2013), using a criterion of ± 3 MAD.

Our previous work indicates that this approach is less feasible in the selective response task because the time available for participants to make a response is limited by the experimental design and because go responses are infrequent in some conditions, reducing the number of reaction time data points. We will select an appropriate cut-off (likely <100 ms) to remove any particularly fast responses in each condition of the selective response task.

M8 How will missing data be handled?

See M6. No other missing data are anticipated.

M9 Other information (optional)

Conditions and design.

M10 Type of study and study design

This is an experimental study with the addition of two questionnaire measures.

There are two experimental tasks, a choice reaction time task and a selective response task. Each task has two within-participant factors: inhibitory load (2 levels), and memory load (2 levels), creating 4 conditions of each task.

M11 Randomization of participants and/or experimental materials

Each task will be presented as a coherent block with a short break in between the two tasks, with half of participants receiving the choice reaction time task first and half receiving the selective response task first. Within the choice reaction time task the two conditions with the same level of inhibition will be blocked together and the order of presentation of these two inhibition blocks will be counterbalanced across participants. In addition, half the participants will receive the low memory condition of each inhibition block of the choice reaction time task before the high memory condition of each inhibition block of that task as well as beginning the choice reaction time task with the low memory condition; the other half of participants complete high memory conditions before low memory conditions. When combined factorially these manipulations produce 8 possible orderings of the experimental task conditions.

M12 Measured variables, manipulated variables, covariates

Reaction times and accuracy of all keypress responses will be recorded. Both will form dependent variables for the analyses although any analysis of reaction times will employ only those associated with correct responses. These will be the primary variables used to explore all hypotheses and exploratory research questions. Omission and commission errors will also be examined in the selective response task as a complement to accuracy.

However, our current work is also exploring the utility and reliability of a range of other measures from these tasks, including response time variability, a combined accuracy-RT measure (Draheim, Hicks, & Engle, 2016), and signal detection measures of sensitivity and bias in the selective response task. Depending on the outcome of those ongoing studies these measures may also be included in our analyses.

M13 Study Materials

Each condition of each task involves a stimulus set of four items (coloured shapes). Each shape of a given colour is only employed in one condition across both tasks.

M14 Study Procedures

The choice reaction time task is a version of the spatial conflict or Simon paradigm. On any trial a blank screen is presented for 200ms followed by the presentation of a stimulus to either the left or right of the screen. The stimulus remains on screen until the participant makes a response using the left or right key. Accuracy and reaction time will be recorded.

The four cells of the task design are formed by crossing two levels of memory load with two levels of inhibitory load.

In the low memory condition, two stimuli correspond to a left response and two stimuli correspond to a right response. However, both left stimuli will be the same colour (e.g., green) and both right stimuli will also be the same colour (e.g., yellow) to minimise memory demands. In the high memory condition four stimuli are again used but no cues to the status of any stimulus is given. In addition, while two stimuli will share one colour and the other two share a different colour, there will be no 1:1 mapping between colour and required response. The participant therefore has to hold in mind the four rules that determine which two stimuli are associated with a left response and which two are associated with a right response.

The two levels of inhibition derive from the difference between 'compatible' and 'incompatible' trials. On compatible trials the stimulus is presented on the side corresponding to the response associated with it; on incompatible trials the stimulus is presented on the side opposite to its associated response, introducing an inhibitory

demand.

Each memory condition will contain 128 trials (64 compatible, 64 incompatible). Equal numbers of each of the 4 stimuli will be presented in each memory condition. Similarly, the number of compatible and incompatible trials in each memory condition will be equated across stimuli. Immediate repetitions of a stimulus will be allowed. The trial sequence in each memory condition will ensure an equal number of 'location stay' and 'location switch' transitions. Similarly, the number of 'response stay' and 'response switch' transitions (making the same response vs. making the other response) will be balanced. In addition, the number of transitions in each of the four combinations of these two transition types will be approximately balanced within each memory condition.

Testing time = 10 minutes.

The selective response task combines aspects of previous Go/No-Go and CPT paradigms, but with a memory load added to the task so that participants need to remember different rules for 'go' and 'no-go' trials. On any trial a blank screen is presented for 350ms followed by the presentation of a stimulus in the centre of the screen for 650ms. Participants are given a total of 1000ms to make a response. The task involves pressing a key (the space bar) for stimuli associated with a go response to advance to the next trial and withholding any key press for stimuli associated with a no-go response. Accuracy and reaction time (for just go responses) will be recorded. The four task conditions are formed by crossing two levels of memory load with two levels of inhibitory load. In low memory conditions, two stimuli correspond to a go response and two stimuli correspond to a no-go response. However, both go stimuli will be the same colour (e.g., red) and both no-go stimuli will also be the same colour (e.g., blue) to minimise memory demands. In high memory conditions four stimuli are again used but no cues to the status of any stimulus is given. In addition, while two stimuli will share one colour and the other two share a different colour, there will be no 1:1 mapping between colour and required response. The participant therefore has to hold in mind the four rules that determine which two stimuli are associated with a go response and which two are associated with a no-go decision.

Each condition will contain 160 trials. Conditions with a high level of commission inhibition (low memory high commission inhibition, high memory high commission inhibition) will be made up of 80% 'go' trials and 20% 'no-go' trials. In these conditions the greater frequency of a go responses means that a greater degree of inhibition is needed to withhold a no-go response. Conditions with a high level of omission inhibition (low memory high omission inhibition, high memory high omission inhibition)

will be made up of 20% 'go' trials and 80% 'no-go' trials. In these conditions the infrequency of a go responses means that the participant needs to employ sustained attention to avoid making omission errors to the go stimuli.

The frequency of go vs no-go stimuli in any condition is determined by the rules described above; however, the two go stimuli will occur as often as each other as will each of the two no-go stimuli. Immediate repetition of a stimulus will be allowed.

Testing time = 20 minutes.

Autistic traits will be measured using the Comprehensive Autistic Trait Inventory (CATI; English et al. 2021) and Attention Deficit Hyperactivity Disorder (ADHD) using the ADHD self-report scale (ASRS; Kessler et al., 2005).

M15 Other information (optional)

Analysis plan

AP1 Criteria for post-data collection exclusion of participants, if any

Any participant who is not significantly above chance ($p < .05$) in terms of accuracy for their average performance across both memory conditions of the choice reaction time task will be excluded from data analysis of that task.

The presence of outlier levels of performance on the selective response task will be examined using two d' measures of sensitivity [$z(\text{hits}) - z(\text{false alarms})$], one for performance across all trials in the two high omission inhibition conditions and one for performance across all trials in the two high commission inhibition conditions. Any extreme outlier (>3 SD) on either d' measure will have their data removed from analysis of that task.

In addition, an attention check question will be built into each questionnaire, and any participant who fails to complete either of these questions correctly on either questionnaire will have all of their data excluded from the study.

AP2 Criteria for post-data collection exclusions on trial level (if applicable).

AP3 Data preprocessing

AP4 Reliability analysis (if applicable).

AP5 Descriptive statistics

See M12

AP6 Statistical models (provide for each hypothesis if varies).

Bayesian ANOVAs will be used to test H1 and H2. These will test the need to include each of the main effects and their interaction in the model, with the within-participants factors of memory load and inhibitory load.

E1 and E2 will be examined using individual differences approaches. Correlations between variables will initially be examined using Pearson r values. Subsequent exploratory analyses will explore whether regression and factor analytic approaches can be used to extract memory load and inhibitory load variables/factors that will be correlated with questionnaire performance.

E3 will be explored using Bayesian ANOVAs.

AP7 Inference criteria

Bayes factors of 3 and above will be taken as positive evidence for an effect or difference in models (Raftery, 1995); Bayes factors of $1/3$ or less will be taken as positive evidence for a null effect. Where frequentist statistics are used an alpha level of .05 will be employed.

AP8 Exploratory analysis (optional)

See AP6 in relation to E3

AP9 Other information (optional)

Other information, optional

O1 Other information (optional)

This study is a student research project conducted as part of Ms Izzy Murcutt's and Ms Emma Wilson's Masters degree.

It parallels a pair of ongoing studies that manipulated memory and inhibitory load in a similar fashion separate versions of the same tasks but while employing more conditions, fewer participants, and a different questionnaire measure of autistic traits, see:

<http://dx.doi.org/10.23668/psycharchives.4610>

<http://dx.doi.org/10.23668/psycharchives.5069>

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