T1 Title: The Interaction Between Working Memory and Inhibition in a Selective Response Task

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T3 Date of Preregistration

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T4 Versioning information

1

T5 Identifier

KTGNG1

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: 110221116671)

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

No, we don't plan to make the code available

T12 Optional: Standard lab practices

<<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

This study employs a novel selective response task modelled on previous usages of the continuous performance test and the Go/No-Go task. Memory and inhibitory loads are manipulated orthogonally across conditions. We also explore the correlations between the inhibition and memory components and measures of autistic and ADHD-related traits.

A3 Participants

A minimum of 48 participants will be recruited for an online study.

A4 Study method

The experimental task involves making ‘go’ or ‘no-go’ decisions to each of four possible stimuli that appear on the computer screen. The six task conditions are formed by crossing two levels of memory load with three levels of inhibitory load. Memory load is manipulated by varying the number of rules needed to remember stimulus-response mappings, inhibitory load by the relative frequency of go vs. no-go 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. One 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 employ a novel selective response task. This is modelled on previous usages of the continuous performance test (CPT) and the Go/No-Go task (GNG). In our task we orthogonally manipulate the memory load across conditions of the task 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. Note that inhibitory load varies in two directions relative to our baseline conditions (see methods).

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. This is something we will examine and, if necessary, modify in future studies.

I4 Exploratory research questions (if applicable; E1, E2, ...)
E1 - we will examine the correlations between the different conditions of the task.
E1a - a question of interest is whether the two manipulations of inhibition are related to each other (i.e., do individuals who make more errors of commission in high commission conditions also make more errors of omission in high omission conditions, and vice versa).

E2 - we will explore the reliability and sensitivity of a range of dependent measures in addition to accuracy and response time, specifically: response time variability, signal-detection measures of 'accuracy', number of commission errors and number of omission errors.

E3 - we will examine the associations between these different measures of task performance and self-reported measures of autistic traits and ADHD traits.

E4 - we will explore the effects of trial transitions in the task. Specifically we will compare performance on pairs of trials involving a) immediate stimulus repetitions, b) a change of stimulus without a change of response, c) a change of both stimulus and response.

E5 - this study is being planned in conjunction with a separate study examining the same issues in a choice reaction time (Simon) task. If we are able to complete both studies within a comparable time-frame we would seek to combine the datasets to carry out comparable analyses on each.

Method

M1 Time point of registration
Registration prior to creation of 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 is a novel study and part of its purpose is to determine the reliability of the task conditions and the size of any effects. We aim to test at least 48 participants. This is twice the number of counterbalancing variations in the experimental design and provides at least 80% power to detect a correlation of .4 or above. We will carry out no analysis of data prior to the completion of testing.

M4 Participant recruitment, selection, and compensation
Participants will primarily be recruited through the lead researcher's school's 'experimental hours scheme' for undergraduate participants. If it is not possible to recruit the full sample in this way then Prolific will be used to recruit further participants, who will be payed 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 any of the conditions of the experimental task their data will be exlcuded from all analyses. We will seek to replace such an individual with an additional participant tested under the same counterbalancing schedule. If a participant completes the conditions of the experimental task but fails to complete one or both of the questionnaires then their data will be included in any analysis of experimental task performance and in correlational analyses with any completed questionnaire.

M6 Masking of participants and researchers
No masking will take place. The experimenter will be aware of the counterbalancing schedule that the participant has been assigned to.

M7 Data cleaning and screening
Our general approach to reaction time outliers is to trim using the Median Absolute Deviation (MAD) method described by Leys, Ley, Klein, Bernard, & Licata (2013), using a criterion of +/- 3 MAD. However, we are not yet certain that this approach will be feasible in this task because the time available for participants to make a response is limited by the experimental design. It is therefore highly likely that reaction time distributions will be curtailed, which may make the MAD approach inappropriate. If so, then we will select an appropriate cut-off (likely <100 ms) to remove any particularly fast responses in each condition of the 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.

The two within-participant factors are: inhibitory load (3 levels), and memory load (2 levels), creating 6 conditions of the experimental task.

M11 Randomization of participants and/or experimental materials
The order of presentation of conditions within each task will be counterbalanced. Specifically, all of the conditions with the same level of inhibition will be blocked together, though presented in a varying order across participants within these blocks. The order of presentation of the inhibition blocks will also be counterbalanced across participants. This produces 12 possible orderings of the task conditions.

In addition, we will employ two versions of the trial set sequence within each level of inhibition. Half the participants will have trial set A associated with the low memory condition at that level of inhibition and trials set B associated with the high memory condition. Half of participants will have the opposite allocation. This produces a total of 24 different ordering x stimulus set combinations.

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.

In addition, we will calculate response time variability in each condition and employ this as a further dependent variable, and we will explore the utility of a combined accuracy-RT measure (Draheim, Hicks, & Engle, 2016). We will also calculate signal detection based measures of sensitivity and bias which will also be employed as dependent variables. We will also measure the number of omission and commission errors made in each condition.

H1, H2, E1 and E3 (and potentially E5) will be tested using all of the above dependent variables given that our exploratory research question (E2) aims to examine the extent to which different measures are reliable and sensitive. However, we may place some of

these analyses in supplementary material to any paper rather than reporting all of them in the body of the text. E4 will be primarily explored using RTs.

M13 Study Materials

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

M14 Study Procedures

The experimental task is a selective response task (akin to a Go/No-Go task or CPT paradigm) where memory load is 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 200ms followed by the presentation of a stimulus in the centre of the screen for 800ms. Participants are given a total of 2000ms 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 six task conditions are formed by crossing two levels of memory load with three 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., blue) and both no-go stimuli will also be the same colour (e.g., yellow) to minimise memory demands. In addition go stimuli are always presented with a visual cue (a tick) embedded within them which makes clear that the participant has to press the spacebar for these stimuli (and not for the two no-go stimuli). 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. Conditions with a low level of inhibition (low memory low inhibition, high memory low inhibition) will contain a total of 120 trials, made up of 50% ‘go’ trials and 50% ‘no-go’ trials. Conditions with a high level of commission inhibition (low memory high commission inhibition, high memory high commission inhibition) will contain a total of 300 trials, 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 also contain 300 trials, 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.
Equal numbers of each of the 4 stimuli will be presented in the two low inhibition conditions. The frequency of go vs no-go stimuli in the other conditions is determined by the condition 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 any given stimuli will be avoided.
Anticipated testing time = 40 minutes.

Autistic traits will be measured using the Short Autism-Spectrum Quotient AQ (AQ-S; Hoekstra et al. 2011) 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 all conditions of a task will be excluded from data analysis.

In addition, two attention checks will be built into each questionnaire, and any participant who fails to complete both 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 best fitting model, with the within-participants factors of memory load and inhibitory load. Because the manipulation of inhibitory load operates in two opposing directions relative to the low inhibition condition (prompting either omission or commission errors) we may supplement the main analysis with analyses that separately compare each pair of high inhibition conditions (either high commission inhibition or high omission inhibition) with the 'baseline' conditions performed under low inhibition.

E1 and E3 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.

E2 will be explored by simply comparing (without formal statistical inference) the relative patterns of effects and inter-relations between constructs using the range of dependent measures we will collect/extract.

E4 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 our first experimental test of this novel experimental task with adults.

However, we are planning to run a comparable study where we manipulate memory load in a similar fashion in a different test of inhibitory control. As E5 notes, we may conduct formal comparisons between the current data set and the data emerging from this other study.

References

R1 References
Draheim, C., Hicks, K. L., & Engle, R. W. (2016). Combining reaction time and accuracy: The relationship between working memory capacity and task switching as a case example. Perspectives on Psychological Science, 11, 133-155. doi:10.1177/1745691615596990

Leys, C., Ley, C., Klein, O., Bernard, P., & Licata, L. (2013). Detecting outliers: Do not use standard deviation around the mean, use absolute deviation around the median. Journal of Experimental Social Psychology, 49, 764-766. doi:10.1016/j.jesp.2013.03.013

Raftery, A. E. (1995). Bayesian model selection in social research. In P. V. Marsden (Ed.), Sociological methodology 1995 (pp. 111–196). Cambridge, MA: Blackwell.

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