Focus:

The focus of this document is to describe the tasks that will be used in a task-switching paradigm.

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    b. Display and motor modifications that will minimize confound but retain task properties.
2. Paradigm and Task Parameters:
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    a. An example of a more thorough walk-through of the task with the parameters for a mental visualization.

Task Descriptions:

Each task was chosen for their psychometric characteristics. However, various forms of the task have been created and implemented throughout the years, and each version will reflect in different TACP. Therefore, the essential components of each task are clarified below. This will highlight what cannot be modified for the sake of minimizing display or motor confounds (potential immodifiable confounds) vs what we can do to minimize display and motor confounds (proposed modification). All the following descriptions were based heavily on the supplementary materials in Hampshire et al 2012 and Eyal et al 2019 in press.

1. All Tasks:
    a. Motor response will be equivalent across all 3 tasks
    b. Equivalent response time allotment per task
    c. We are not increasing or decreasing difficulty as to limit the variability in the tasks as little as possible.
    d. Rationale for tasks: the three originally most psychometrically opposed tasks were the Digit Span (DS), Spatial Rotation (SR), and Self-Ordered Search (SOS). However, the display and motor confound of the SOS were much larger than those of the SR and DS. However, the Spatial Span (SS) is another task that has similar psychometric properties to the SOS but is much more amenable to display and motor modifications.
2. Digit span: The digit span evaluates working memory by employing the phonological loop. In this task, a sequence of 4 numbers within a shaded box on the stimulus grid appears on a screen one after another. Traditionally, the sequence is repeated by the participant by entering the numbers in the ordered they appeared in a keypad. This is a variant of the WAIS-R intelligence test that evaluates working memory.
    a. Potential modification: To reduce the motor confound of multiple vs one click, a selection of answers can be provided, depicting the numbers from the sequence in a variety of orders. The participant would choose which answer represents the correct sequence. This would not interfere with the cognitive property of interest in this task, the phonological loop.
3. Spatial rotation: This task evaluates the ability of the participant to mentally rotate objects. The variant in Hampshire et al 2012 employs 2D grid of 4 colored squares as the stimulus. The grid is

then rotated in a multiple of 90 degrees and displayed among other grids that differ by the position of a square. The participant must select which grid is the rotated version of the stimulus.

a. Potential modification: the colored squares will be replaced with a single color in order to match the colors used in the other tasks. This modification minimizes display confounds and will not affect the psychometric foundation of this task, which is to evaluate mental spatial rotation. Also, use a sequence light up of squares one after the other in the 4*4 grid as in SS task, then hold the display of end result whilst presenting the answer choices as before. Addresses the "flashing display" confound without compromising the psychometric foundation.

b. Potential immodifiable confound: In the SS and DS the boxes disappear after the initial presentation; in the SR they build upon one another. The resulting end image is a visually more complex image. However, this is our only display confound thus far. It is arguable whether this confound will compromise the objective of this task- to measure the reconfiguration in TACP of switching between three cognitively disparate tasks. Additionally, behavioral piloting will determine whether removing the stimulus before presenting the answers (as in the SS and DS) will be too difficult; otherwise, leaving the stimulus up while allowing the participant to answer is an additional display confound.

4. Spatial Span: This task requires a short-term spatial memory. 16 squares are placed on a 4 * 4 grid that flash in a random sequence one after another. Traditionally, the participant has to repeat the sequence by clicking on the squares in the same order as presented.
   a. Potential modification: Rather than instead of clicking on the squares in the order they were presented, the answer grids will display one containing the final sequence, with the others displaying the sequence that is incorrect by one box, similar to the digit span. This follows the same rationale; answer selection still requires utilization of the short-term memory visuospatial sketch pad.

Paradigm and Task Parameters:

5. Task and rest blocks: We need rest blocks to both prevent fatigue and generate a baseline to compare task activation to. We can have four task blocks with three minutes of rest between blocks 1-2, 2-3, and 3-4.
6. How long should each task be?
   a. This will require behavioral piloting to determine a performance plateau. Ines suggested having piloting where participants (n=20?) complete 40 trials of each task, and we determine where the centered performance plateau is. We can then vary the number of trials after the number of trials where performance levels off (below written as X_{crit_trials})
   b. For DS, SS, and SR, each have 4 digits or squares box to remember. If each box is presented for 500 ms, 500 ms per box * 4 boxes = 2000 ms. Allow 2000 ms to respond before next trial begins. Therefore, trials = 4000 ms. or 4 s.
   c. Task length should vary to prevent preparation for the switch. The length of the task will depend on how many trials it takes to level out the switch cost and for a performance plateau. We provided the generous assumption of 12 trials; this will change depending on Adam/Will/Rich's input as well as behavioral piloting. After the initial component the task length (TL) would extend by a variable number of trials between 1 to 12 ($1\text{-}12_{var\_trial}$).

i. To be generous, 12 trials = (4000 * 12) + (50 * 12) = 36600 ms (36.6 s, or roughly 2/3 minute)

ii. Equation 2: $TL = (X_{crit\_trials} * 4_s) + ([1\text{-}12_{var\_trial}] * 4_s)$

7. What are the stages of the task switch?
    a. After the number of trials ends, we have a cue of "Next Task: ___" that lasts either 4000 ms or 500 ms. Half the switches should be after a 4000 ms cue.
    b. We could then observe whether the same network dynamics occur in the shorter vs longer task switch, just overlapping into actual task performance, and whether this is what presumably manifests as a higher switch cost for the shorter interval.
    c. This design also allows us to characterize slow oscillations during task switch as well as contain a temporal resolution amenable to fMRI as well as EEG
8. How many switches can we have in an hour?
    a. This will take careful matrix design. There needs to be an equal number of switches (6 types) as well as an equal number of repeats and switches; for example, an equal number of DS → DS → SS or SR → SR → DS.
    b. We have 3 tasks, each approximately 2/3 minutes long. We have six different types of individual switches and six types of repeat switches (see table below)
    c. Depending on the total number of switches possible (x) we have (x/2) 4000 ms task switch cues and (x/2) 500 ms task switch cues.
    d. Some rough math:
        i. Assume there are 3, 13-minute blocks per paradigm interspersed by 3-minute rest intervals.
        ii. Assume each task is a minute long (some just barely longer than X_{crit_trials} and some twice as long)
        iii. If there are 9 tasks, then there are 8 switches, there could be four 4000 ms switches and four 500 ms switches.
            1. If there are 8 switches per block * 4 blocks, then there are 32 switches per run. There are 12 unique switches (see table below). Assuming this math is anywhere near close, we can almost get three of each type of switch per participant.
            2.

Single Switch		Repeat Switch	
Description of Switch	Unique Switch Type	Description of Switch	Unique Switch Type
SS → DS	A	SS → A	G
DS → SS	B	SS → E	H
SR → DS	C	SR → C	I
Ds → SR	D	SR → F	J
SS → SR	E	DS → B	K
SR → SS	F	DS → D	L

        iv. Therefore; (4000 * 4) + (500 * 4) = 5 mins + 9 mins = 14 mins.

Basic display:

The main display is a white screen. Paradigm cues are 70-point Times New Roman font. The paradigm will be an hour long. During each of the three tasks the stimuli grid is a 5” x 5” square formed into a grid of 4 * 4 blocks. The stimuli grid is on the left side of the screen as viewed by the participant. After stimuli for each task are presented, a 50 ms interval occurs, then the answer grids appear on the right side of the screen. Each answer grid is ¼ the size of the answer grid.

Task SOP

1. **Press anywhere to begin**
    a. *Participant clicks anywhere*
2. **Next Task: Spatial Rotation**
    a. Either 4000 or 500 ms presentation
3. Screen with stimuli grid pops up four boxes appear, one after another.
    a. 500 ms presentation of each box
    b. Each box fills a section of the stimuli grid with a light blue. A number in bold Times New Roman font is centered in the box. For this task, all boxes and numbers are the same per trial. The number can change between trials.
4. After the last square appears, 500 ms elapses, then all colored squares disappear.
5. 50 ms interval between the clearing of the stimuli grid and the three answer choice grids appear.
6. Each of the three answer grids contain four squares. One answer grid has a rotated version of the stimuli in a 90 degree interval. The other two answer grids are also are rotated versions of the stimuli grid, but are incorrect by one square
    a. 90-degree interval is determined by a randomizer for a 90, 180, or 270 forced rotation of the stimuli as one answer choice, and the other two are rotated/ modulated versions
    b. *Participant clicks their answer*
7. Participant has 2000 ms to answer before it is counted as incorrect and the next trial begins.
8. Task length varies as determined by Equation 2.
9. After completing the designated number of trials, cue appears.
10. **Next Task: Digit Span**
    a. 4000 ms or 500 ms presentation (see rationale above)
11. The stimuli grid appears.
12. Numbers within boxes are presented in the top left corner of the stimuli grid, one after the other, in 500 ms intervals, for four numbers ranging from 0 – 9 without repeats.
13. 50 ms interval between the clearing of the stimuli grid and the three answer choice grids appear.
14. The answer grids appear, each containing a sequence of the presented numbers within the top panel of the answer grids. One sequence presents the numbers in the order they were presented in. The others contain the same numbers, but are in an incorrect order.
15. Participant has 2000 ms to answer before it is counted as incorrect and the next trial begins.
16. Task length varies as determined by Equation 2.
17. **Next Task: Spatial Span**
18. The stimuli grid appears. One by one, four colored squares with numbers in them appear for 500 ms, then disappear in a pattern across the Stimuli grid.

19. The answer grids pop up. Each grid contains a pattern of four colored squares, and one is in the pattern as they appeared in the stimuli.
20. Participant has 2000 ms to answer before it is counted as incorrect and the next trial begins.
21. Task length varies as determined by Equation 2.
22. After 13 minutes a cue displaying **Rest** appears
23. The first of three 3-minute rests occur.
24. After the rest is over, the **Next Task** cue appears. The next 13-minute block of tasks begins.
25. After the four blocks are completed, a cue of **The session is over** appears, and the participant has completed the task.

Minimizing Interference and Confounds:

1. To minimize bottom-up interference we will control for display confounds. Color and luminosity can be processed using the MATLAB script rgb2gray for extracting luminance values, and mean2 for extracting contrast values. We can extract these values per stimuli per set and do an ANOVA between group (the tasks), luminance, and contrast to make sure there is no interaction or effect of the stimuli (Nikolla et al 2018; rdb2gray, 2016; mean2, 2016).
2. To minimize reward history interference, we are not providing feedback for task performance. At the end of piloting sessions, we can ask if participants enjoyed or felt more successful during one task vs the others, and see if this is related to their performance. For example, if a participant feels like they performed better on one task than another, it may change their perception/ preparation for the task and potentially exhibited a lower switch cost at the beginning of the preferred task. Another means of addressing this is, during piloting, to ensure task difficulty and switch costs are relative to one another (measured in MRT and accuracy).
3. To minimize selection history interference and motor confounds, we will counterbalance the amount of motor responses for each of the answer grids.

Questions for Adam, Rich, and Will:

- Can all three of you send me whatever code you have for the tasks? I understand it will need to be heavily modified, but not coding from the ground-up will be immensely helpful.
- What is the average score on the digit span? Will 4 digits be too easy? Is there data on when the performance centers?
- What are your thoughts on this paradigm? Please poke as many holes into it as possible, as it helps identify weaknesses that I would not be aware of at this stage in my learning. THANK YOU SO MUCH!