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Programming an n-Back task in Qualtrics using HTML and JavaScript

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Abstract ■ The n-back task is an extensively used cognitive test that assesses working memory. The task is well-suited to virtual administration as it reliably produces similar results to in-person administration and is easily adapted to asynchronous operation. However, the procedure to program this task into various computer programs and software is not widely known. Therefore, this tutorial aims to provide researchers with simple yet detailed step-by-step instructions on how to program an n-back task in Qualtrics using HTML and JavaScript. This tutorial is meant to be easily followed by the layperson without extensive knowledge of computer programming.

Keywords ■ n-back, working memory, cognition, neurocognitive tests, computer-based psychological testing. **Tools** ■ Qualtrics, JavaScript, HTML.

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Introduction

Conducting research online has been an accepted practice for scientists since the widespread use of the internet became commonplace (Kraut et al., 2004). With the onset of the COVID-19 pandemic in 2020, many researchers moved their work either partially or fully online (Shamsuddin et al., 2021). Although many industries have returned to in-person operations as public health safety measures have been reduced, some researchers prefer to continue conducting their testing and analysis digitally, citing the reduction in both practical costs and barriers to accessibility (Howlett, 2022; Shamsuddin et al., 2021).

Clinical and research settings have benefitted from providing online services to participants and clients. While in-person assessment remains highly valued, virtual options expand service delivery and may allow for at-home monitoring and measurement (Hewitt et al., 2020). There has been significant research into neurocognitive assessment in virtual medical care. Previous research comparing digitally gathered data with data gathered in person has demonstrated that online testing provides similar results to the results obtained from in-person testing (Brearly et al., 2017; Carr et al., 2020). For instance, a meta-analysis investigating 12 studies on virtual neuropsychological assessments determined that results were not affected by the online format (Brearly et al., 2017). A more recent systematic review found specifically that attention and working memory tasks, among others, were valid across in-person and virtual formats (Marra et al., 2020). Another strength of computer-based assessments is that it ensures that the tasks are administered in a standardized manner thereby reducing the impact of experimenter variables on the findings (Fischer & Milfont, 2010). It is therefore increasingly important to have a wider range of experimental assessments available in an online format and is also particularly important for replication purposes (Nosek et al., 2022).

Neurocognitive assessments include a wide range of tasks that assess various cognitive domains such as attention, memory, executive functioning, processing speed, and language (Harvey, 2012). Executive functioning is an umbrella term for a set of mental processes involving goal selection, planning, execution, and working memory (Anderson, 2002). Working memory consists of a structure of elements that allow for the temporary retention and manipulation of information (Baddeley, 2010; Chai et al., 2018; Logie et al., 2021). While different models for working memory exist, the classic tripartite model described by Baddeley (2010) is reflected in the strategies employed when completing the n-back task (León-Domínguez et al., 2015). Baddeley's model categorizes memory into elements including the visuospatial sketchpad, phonological loop, and central executive (RepovŠ & Baddeley, 2006; Tulving & Craik, 2000). The visuospatial sketchpad and phonological loop components operate the visual-spatial and verbal working memory while the central executive controls attention processes (León-Domínguez et al., 2015; RepovŠ & Baddeley, 2006; Tulving & Craik, 2000).

n-back Task

Continuous performance tests (CPT), such as the n-back, are frequently used to measure specific cognitive domains such as attention and working memory (Borgaro et al., 2003; Lamichhane et al., 2020; Owen et al., 2005) in clinical and research settings (Elliott, 2003; Schoofs et al., 2008). The n-back task was originally designed in 1953 to assess the effects of mental fatigue on civilian aircrew (Kane & Conway, 2016). However, it is now widely used in research and clinical settings with individuals experiencing various conditions such as dementia and multiple sclerosis (Forn et al., 2007; Parmenter et al., 2006) as well as with individuals who are considered healthy (Schmidt et al., 2009). The n-back task requires participants to identify targets and non-targets in a discrimination task by recognizing if a specific stimulus was previously presented (Owen et al., 2005; Pelegrina et al., 2015). Stimuli are quickly presented one at a time, with a brief delay between each stimulus presentation. The stimuli can be visual or verbal with some studies using images while others have used unspoken and spoken words (Forn et al., 2007; Shucard et al., 2011). The task increases in difficulty as participants are asked to identify what was presented an increasing number of stimuli previously shown. As such, the number of stimuli previously presented that need to be identified is represented with the variable n (e.g., 1-back, 2-back). Participants are required to continuously manipulate information through comparison and rejection with greater n demanding faster storage and retrieval outside of the focus of attention (Oberauer, 2002; Pelegrina et al., 2015).

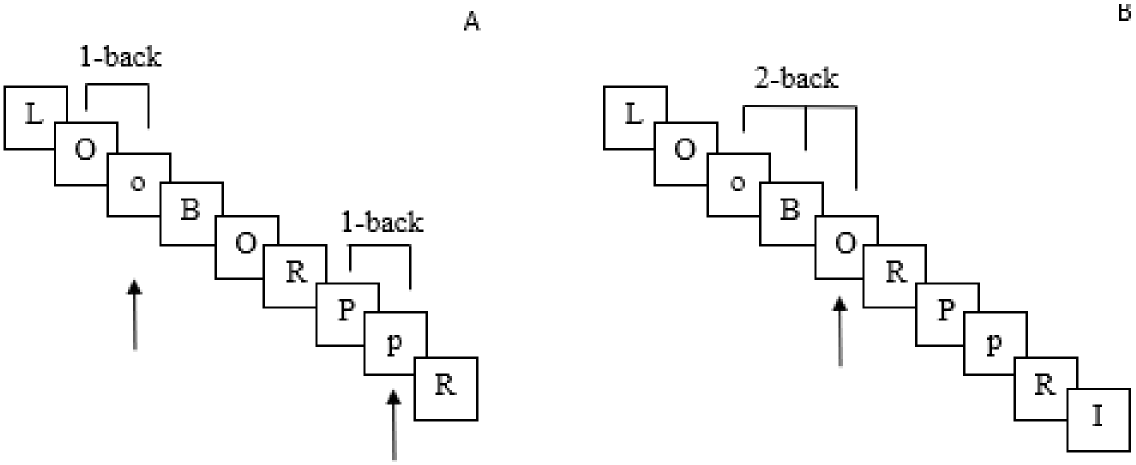
Administration. To administer the n-back task, participants should be in a quiet space free from distractions as the task requires sustained attention (Gajewski et al., 2018). When participants are administered the n-back task using an online program, a sequence of stimuli, either visual or verbal, is briefly presented. For each stimulus, the participant must determine if it matches a stimulus presented n stimuli previously shown by pressing on the space bar or otherwise indicated, as quickly as possible. At the 1-back condition, for example, the stimulus must be compared to the stimulus that immediately preceded it. For instance, imagine the following letters appearing one at a time on the screen for 1 second each: L, O, o, B, O, R, P, p, R, l. When asked to identify which letter was shown 1 letter previously, the participant would respond as follows: L, O, o (press the spacebar when "o" appears as the letter "O" appeared 1 letter previously), B, O, R, P, p (press the spacebar when "p" appears as the letter "P" appeared 1 letter previously), R, l. See figure 1A for a visual representation of the 1-back task. This condition tends to rely more on attentional processes than conditions with greater n (Watter et al., 2001). At the 2-back condition, the stimulus is compared to the stimulus presented 2 positions beforehand. Using the same sequence of letters as an example, the participant would respond as follows: L, O, o, B, O (press the spacebar when "O" appears as the letter "o" appeared 2 letters previously), R, P, p, R, l. See figure 1B for a visual representation of the 2-back task. The same procedure would be applied for all conditions in which n increases. As n increases, so does the cognitive load with a resulting drop in performance (Braver et al., 1997). The simultaneous dual-processing requirements of the n-back task meet face validity criteria for assessing working memory, although there is recent divergent evidence that suggests the n-back task weakly correlates with change detection, another working memory task (Frost et al., 2021; Gajewski et al., 2018).

Scoring. The participant's score is a comparison of correct identifications (hits) to failing to respond to targets (omissions) when the stimulus is presented. The score also considers any false alarms (commissions) when the stimulus is not presented, and the participant responds positively. Omission errors are more common than commission errors in the n-back task, and there is evidence suggesting that the two types of errors are related to different processes in working memory such as recognition and retrieval (Meule, 2017). The score is defined by d' using the formula $d' = Z_hit - Z_FA$ where Z is the transformation of the two distributions (Macmillan & Creelman, 1990). Some studies have also measured reaction time (Hur et al., 2017; Jaeggi et al., 2010). However, there appears to be more significant variability in accuracy than reaction time and it may therefore be more meaningful to analyze accuracy (Hur et al., 2017; Meule, 2017). Previous research found a correlation between accuracy and fluid intelligence, defined as the ability to solve novel problems, when researchers compared the n-back task to other measures of working memory such as operation and reading span tasks (Jaeggi et al., 2010; McGrew, 2009).

Objective

While the n-back task has been previously adapted to virtual formats (León-Domínguez et al., 2015), we are the first to provide a detailed tutorial for programming the task into Qualtrics using JavaScript and HTML with a real-world example for the sake of clarity. As the n-back paradigm is prevalently used in cognitive research and neuropsychology (Elliott, 2003; Schoofs et al., 2008), among other do-

Figure 1 ■ Visual representation of the 1-back (1A) and 2-back (1B) task using a fictional example for illustrative purposes. The arrows in both figures (1A and 1B) represent when the spacebar, or otherwise indicated, should be pressed by the participant to obtain the correct response.



mains, researchers with even limited knowledge of coding and programming can benefit from this step-by-step guide. Although this tutorial focuses on programming the n-back task in Qualtrics, it can be adapted to a wide range of programs by modifying the JavaScript and HTML codes which can then be embedded in similar interfaces. The generalizability of the provided instructions allows for greater clinical and research implications.

A Step-By-Step Guide to Program the n-back Task in Qualtrics

Tutorial Example

For this tutorial, a fictitious experiment is used to facilitate understanding of the procedure required to program the n-back task in Qualtrics. For this hypothetical study, participants will first be asked to read a consent form to ensure that they fully understand the study objectives and the tasks that they will be asked to complete prior to commencing the experiment. Participants that consent will be directed to complete an n-back task. The n-back task in the fictitious experiment starts with a practice 1-back session in which a sound notifies participants of correct hits. Researchers may use other types of notifications to increase accessibility for participants. Participants then complete three blocks of 30 trials each of 1- and 2-back sequences, without a sound to signify a correct response. Participants who achieve at least 20 correct responses during the 2-back task will proceed to a 3-back sequence. If participants do not obtain this score, they will be directed to the end of the study where a message thanking them for their time will appear. During the three sequences (1-, 2-, and 3-back) of 90 trials each, the following letters will appear in the center of the screen in font size 30 pt for 1 second for each in a randomized order: A, B, C, D, F, H, K, L, M, N, O, P, Q, R, X. Finally, a thank you message will appear on the screen to inform participants that the study is complete. Overall, this study should take approximately 25 minutes to complete.

Step 1. Create New Project in Qualtrics

To access Qualtrics, select the following link: https://login.qualtrics.com/. Should the reader have an account, they will enter their username and password to log into the webpage. If the reader does not have an account, select *Create Account*. For this tutorial, we will assume that the reader already has a free or paid Qualtrics account. Once the user signs in to Qualtrics, the default window that appears is the Qualtrics *Home* screen. This default screen may vary depending on the user's settings. Next, select *Create a new project* in the bottom left corner panel. A new window will appear in which the user will need to select *Project > Survey* under *Create a Project – From Scratch > Get started*. In the new webpage, enter the title that you would like to name your project under *Name*, select the folder where you would like to save your project under *Folder*, and then select the type of survey you would like to create under *How do you want to start your survey?*. For this tutorial, we called the project "n-back", saved it under *Projects and Programs*, and selected *Create a blank survey project*. Once a new project is created, Qualtrics automatically generates a multiple-choice question block. In Qualtrics, a *block* refers to a set of questions or activities within a survey. For this tu-

Table 1 ■ JavaScript Script and Corresponding Functions

Instruction	Definition
var	Variable: defines the storage area for data
function	A set ofactions
condition	An if-then statement requiring an action to precipitate a response
loop	A command for an action to be repeated
stimulus	Text that is visible to the participant
array	Multiple values stored in a single variable
timeline	Indicates the order the experiment will follow
//	A comment that will only appear to the reader and does not impact the function of the script

torial, we will remove the multiple-choice block so that we can start the project from scratch. To delete this block, select the three dots beside the multiple-choice question and then select *Delete* from the drop-down menu.

Program Welcome Message (optional). If required for your study, you can create a block with a welcome message or other necessary information that you would like participants to see when they access your experiment. To do this, add a new block by selecting the *Add New Block* button which is found beneath each preceding block. The user may wish to rename this block, and any subsequent blocks that are created, so that the project remains organized. For this tutorial, we renamed this block *"Welcome Message"*. To add a text entry in this block, select *Text/Graphic* from the drop-down menu that appears after selecting *Add New Question*. Qualtrics identifies each item within a block as a question. These questions will be referred to as "sub-blocks" for this tutorial. All sub-blocks can also be renamed so that the variables can be easily identified when the data is exported into a spreadsheet. We recommend not using spaces for the sub-blocks as certain statistical software does not recognize titles with spaces (e.g., WelcomeMsg). In the sub-block created, enter the message that you would like participants to see when they access your experiment. For example, *"Welcome to this online memory study. Thank you for your interest in participating in this study. Please select Next to proceed to the consent form prior to starting the task"*.

Program Consent Form (optional). To create a consent form for your study, generate another block and rename the block accordingly (e.g., *"Consent Form"*). Next, double-click on the *Click to Write Question Text* box in the new block that was created, and then select *Rich Content Editor* to add a new text entry and edit the format. In the new window that appears, enter the required information for your consent form. Once you are done editing your consent form, double-click on the main Qualtrics interface so that the text editor window disappears. Within the same block, you can add a specific question where participants can provide informed consent or decline to participate should they wish to not proceed after reviewing the details of the study. To do so, select *Add a New Question* > *Multiple Choice*. In the new sub-block, enter the questions you want to ask participants and the various response options. In our example, we entered *"Please select one of the following options"* in the Click to *Write Question Text* box and provided participants with the following options: *"I have read the form and I consent to participate in the study"* and *"I have read the form and I do not consent to participate in the study"* by editing *Click to Write Choice 1 and 2*, respectively. As consent is mandatory for participating in research, ensure that the settings are configured to only allow participants to respond to one option and that a response is required before proceeding to the next step. As such, select *Allow One Answer* > *Add Requirements* > *Force Response* in the left-hand panel. If participants decline to participate in the study, the user may want to direct them to the end of the experiment. To configure this, select *Skip* under *Question Behavior* in the left side panel. In the new window, select *End of Survey* from the drop-down menu so that participants are directed to the end of the survey should they select *"I do not consent to participate"*.

Step 2. Program n-back Task

Now you are ready to program the n-back task. The n-back task itself is programmed in JavaScript with the HTML script ensuring that the JavaScript functions appropriately in the webpage and then embedded into Qualtrics. HTML allows the user to read text or view the webpage, while JavaScript enables the user to interact with elements within the webpage (McFarland, 2011; Sun & Ryu, 2018). A detailed description of how to create both scripts and then how to program them in Qualtrics is outlined below.

JavaScript. First, you will need to create your JavaScript which can be written in TextPad, JsPsych, or your preferred text editor. The JavaScript utilized in this tutorial uses functions from jsPsych version 6.1 (de Leeuw, 2015), and can be found in Appendix A. As shown in Appendix A, lines 1-10 of the code are used to set up the survey engine in Qualtrics. To hide the *Next* button that appears when the

Table 2 ■ HTML Script and Corresponding Functions

Variable	Definition
 	Indicates a break in the text
<span></span>	Font color and size
<script></script>	Reserved word for loading script blocks
<div></div>	Indicating placement of content

experiment is presented to participants in Qualtrics, lines 14-18 will need to be included in your script. This allows participants to view the n-back task in the full screen without the possible distraction of the *Next* button in the corner as well as ensuring that they do not skip to the next step too quickly by accident. As participants may be using different devices (e.g., computer, tablet, or mobile device) which may modify the layout of the experiment, lines 20-25 can be added to the script to determine the type of device participants are using to ensure that the layout remains consistent across all devices. In the next section, the script initializes the experiment variables including stimuli, the sound indicating a hit, the number of distractors, and the number of targets (lines 26-70). Researchers may choose alternate stimuli from those provided (e.g., L, M, O). To ensure that participants are not distracted by additional windows on their device, lines 77-93 are variables allowing the user to toggle full screen on or off. Should researchers want *Welcome* and *Goodbye* messages to appear on the screen, lines 95-104 can be configured. Likewise, the instructions describing the n-back task to participants are found between lines 106-136. Researchers may want to alter the content of the instructions to accommodate language or the participants' level of understanding. Lines 138-252 should not be altered in any way, as they relate to the mechanics of the n-back task: shuffling the stimuli, creating the trial runs, and alternating the case of the letters systematically with every odd letter being lowercase. However, the variables themselves such as the number of trials and stimuli may be altered to suit the researcher's purposes. For example, in the script provided, a certain number of hits are required to access the 3-back condition. Lines 263-525 of the script should also not be altered as this section generates the practice and condition sequences as well as defines both the trials and the order in which they occur. Notably, JavaScript is sensitive to common punctuation marks including commas and apostrophes. For this reason, avoid contractions even when cumbersome (e.g., use "do not" in place of "don't"). A list of the key variables used in the JavaScript script is listed in table 1.

Once your JavaScript is ready, you can program it in Qualtrics. Start by selecting *Add Block* to create a block specifically for the n-back task. Then, select *Add New Question* and then choose *Text/Graphic* to create a text entry. In the left side panel, select *JavaScript* which will open a new window titled *Edit Question Javascript*. In this new window, delete the existing lines of code and paste the entire JavaScript that you created, and then select Save. For this tutorial, we pasted the content of Appendix A in the JavaScript window. Once the script is successfully saved, the user can click on the main Qualtrics page to close this JavaScript window.

HTML. For this tutorial, the HTML script found in Appendix B was used to ensure that the JavaScript appeared properly on a webpage. Specifically, lines 1 to 24 of Appendix B configure predefined JavaScript libraries that link the HTML script to a file server hosted on GitHub, a storage cloud for web developers to store and access their codes. Afterward, lines 27 to 47 enable you to configure the display stage and background for this visual experiment. Specifically, the display stage refers to the layout and format of the webpage including the color and width of the background (lines 28-32), and positioning of the elements on the screen (lines 34-46). Although it is not required, you may add a brief message if the participant encounters technical difficulties resulting in the n-back task not launching in their web browser (lines 49 to 59). Specifically, you may modify the font size of the text that appears on the screen by editing the number on line 50. The first line of text that participants will see on the screen is shown on line 51 and to ensure that the text starts on a new line, it will need to be separated by "<br>" (line 52). For this study, we chose to ask participants to contact the laboratory should they encounter technical difficulties (lines 55-56) for more than 10 seconds (lines 53-54). A list of the key variables used in the HTML script is listed in table 2.

Once the HTML code has been finalized, it can be added to Qualtrics. To do this, double-click on *Click to Write Question Text* in the same n-back block that was previously created for the JavaScript. Next, select *HTML View* rather than *Rich Content Editor*, which was previously selected to edit the text entry blocks, and paste your HTML script into the *HTML View*. For this tutorial, we pasted the content of Appendix B into *HTML View*. Should you wish to make changes to the HTML script once it has been added in Qualtrics, ensure that you edit the script in *HTML View* rather than selecting *Rich Content Editor* or simply directly editing after double-clicking on the box. This is noteworthy

Table 3 ■ Embedded Data as it Appears in the Qualtrics Results Page

Variables	Score
nBack1FA	1
nBack1MISS	3
nBack2FA	2
nBack2MISS	5
nBack3FA	2
nBack3MISS	3

Note. Numbers will correspond to the total number of false alarms and misses the participant made in each sequence. The numbers in Table 3 are for illustrative purposes.

as editing the display message in the *Rich Content Editor* or by double-clicking the text box could result in your script getting deleted.

Embedding Results. Now that your experiment is programmed, you will want to ensure that data is being saved properly in Qualtrics. To access the JavaScript results of the n-back task, the data must be embedded into Qualtrics. This will allow the results to be exported from the task into the *Results* section of the survey, as shown in Table 3. To do this, add one block before the block containing the n-back task. In our example, this is the *Consent* block. First, navigate to the menu in the upper far left corner of the page to locate the blue clipboard icon. Below the blue clipboard icon is an icon of two connected rectangles where you can locate the *Survey Flow* icon. On the *Survey Flow* page, there is a list of all the blocks within the survey in the order in which they will appear to the participant. Select the block directly above the n-back task and click on *Add Below*. In the new window, click on the *Embedded Data* option below the question *What do you want to add?*. Next, a text box will appear listed as *Create new field or select from drop-down menu* which is where you will need to enter the name of the various n-back variables that you want to score. In this example, these variables correspond to the number of false alarms (e.g., nBack2FA) and omissions (e.g., nBack2MISS) made by the participant, enabling the researcher to score the result using the formula detailed above in the *Scoring* section. Specifically, we typed *"nBack1FA"*, without quotation marks, then clicked *Add a new field* to create another box, and then typed *"nBack1MISS"*, without quotation marks, in the second box. Next, repeat these two steps for all n-back sequences used for your study (e.g., *"nBack2FA"*, *"nBack2MISS"*, *"nBack3FA"*, and *"nBack3MISS"*). Finally, click *Apply* on the bottom right corner of the page to save.

Step 3. Pilot Tests

As with all experiments, it is crucial to review the entirety of the project to ensure that everything was programmed correctly. To do this, select *Preview* and complete every step of the study as though you were a participant. It will also be important to respond to each task to ensure the data is being exported accurately in Qualtrics. Once you have completed a pilot test of your study, select *Data & Analysis* and a new row should appear with the data of your pilot test. Next, select the *Export & Import* > *Export* button to the right of the screen. In the new window that will appear, configure the settings according to the format that you want the data to be exported in. For this guide, we selected *Excel* > *Use Choice Text* and ensured that *Download All Fields* was enabled prior to selecting *Download*. When the new Excel file is successfully downloaded to your desktop, view each column and row to ensure that all the data was correctly exported. If the data was correctly exported, you will need to select *Publish* and then *Save* in the main interface for your project to be able to share it with others.

Step 4. Share Qualtrics Experiment

Finally, there are various methods to share Qualtrics projects. For instance, Qualtrics can generate specific links based on participant identification and email, a QR code, and a URL for the experiment. You can locate these options by selecting *Distributions* and then finding the type of method that you would like to use to share your experiment. In this case, we opted to share an *Anonymous Link* which is a generic URL that will be shared with all participants.

Conclusion

In summary, the n-back task is a well-established measure of working memory that can be adapted in a wide range of methods according to one's research objectives and sample characteristics. The ability to administer an n-back task asynchronously in a virtual format on various computer programs has enormous applications in both clinical and research settings. In a post-COVID reality, both researchers and participants may appreciate the option to conduct experiments online. Therefore, this tutorial gives concise and easy-to-follow instructions for programming a virtual n-back task into Qualtrics or similar platforms that are easily accessible by researchers with a wide range of expertise.

Authors' note

The JavaScript and HTML scripts provided in the Appendices have also been made available on the journal's website. We would like to acknowledge Kristina Munelith-Souksanh and Jane Archibald for their time in carefully reviewing this manuscript.

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Appendix A. JavaScript script for n-back task

```
Qualtrics.SurveyEngine.addOnload(function () {
  /* Appending the  display_stage  Div  using  jQuery  */
  if (document.getElementById("display_stage")) {
    console.log("Found prior to creation");
  } else {
    console.log("Not found prior to creation");
    jQuery("<div id = 'display_stage_background'></div>").appendTo("body");
    jQuery("<div id = 'display_stage'></div>").appendTo("body");
  }
});



Qualtrics.SurveyEngine.addOnReady(function () {
  /*Place your JavaScript here to run when the page is fully displayed */
  /* Hide the Next button */
  var qthis = this;
  qthis.hideNextButton();

  if (
    window.Qualtrics &&
    (!window.frameElement || window.frameElement.id !== "mobile-preview-view")
  ) {
    initExp();
  }
  /* jsPsych.init() in a function */
  function initExp() {
    // General parameters
    var StimDuration = 1500;
    var ISIDuration = 500;
    var nItemsTotal = 30;
    var nItemsTarget = 10;
    var nLeadingDisttr = 3;
    var currentnback = 0; // currentcondition
    var MaxError = 24; //
    var currentTrial = 0;
    // Create n stimulus objects (pictures --just a location -- or letters --html code--).
    var nstim = 15;
    var stim1 = '<p style="font-size:30pt">A</p>';
    var stim2 = '<p style="font-size:30pt">B</p>';
    var stim3 = '<p style="font-size:30pt">C</p>';
    var stim4 = '<p style="font-size:30pt">D</p>';
    var stim5 = '<p style="font-size:30pt">F</p>';
    var stim6 = '<p style="font-size:30pt">H</p>';
    var stim7 = '<p style="font-size:30pt">K</p>';
    var stim8 = '<p style="font-size:30pt">L</p>';
    var stim9 = '<p style="font-size:30pt">M</p>';
    var stim10 = '<p style="font-size:30pt">N</p>';
    var stim11 = '<p style="font-size:30pt">O</p>';
    var stim12 = '<p style="font-size:30pt">P</p>';
    var stim13 = '<p style="font-size:30pt">Q</p>';
    var stim14 = '<p style="font-size:30pt">R</p>';
    var stim15 = '<p style="font-size:30pt">X</p>';
    // create an array of stimuli for convenient programming
    var ListOfStimuli = [
      stim1,
      stim2,
      stim3,
      stim4,
      stim5,
      stim6,
      stim7,
      stim8,
      stim9,
      stim10,
      stim11,
      stim12,
      stim13,
      stim14,
      stim15,
    ];

    // an audio file with woohooo sound
    var snd = new Audio("https://rmg2424.github.io/Dr.-Mid-Nite/woohoo2.wav");
    snd.volume = 0.15;

    /*
   <!-- ******************************** -->
   <!-- Toggle full screen on or off -->
   <!-- ******************************** -->
   */

    var FullScreenOn = {
      type: "fullscreen",
      message:
       "<p>The screen will enter fullscreen mode when you press the button...</p>",
      button_label: "Full Screen",
      fullscreen_mode: true,
    };
    var FullScreenOff = {
      type: "fullscreen",
      fullscreen_mode: false,
    };

    /*
   <!-- ******************************* -->
   <!-- * Welcome & Bye * -->
   <!-- ******************************* -->
   */
    var Show_Bye = {
      type: "html-button-response",
      stimulus: "<p>Thank you for completing this task! </p>",
      choices: ["Continue"],
    };

    /*
   <!-- ******************************* -->
   <!-- * Defining instructions * -->
   <!-- ******************************* -->
   */
    var Show_Ready = {
      type: "html-button-response",
    stimulus:
      "<p>You are now ready to continue the task! </p><p>Reminder: For this study
, there are 3 tasks: first you will be asked to identify which letter appeared <
b>1 letter previously</b> then <b>2 letters previously</b>, and finally <b>3
letters previously </b >. During these tasks, you will not hear a sound
indicating whether you have the correct or incorrect response. Please do not
take breaks during a task. It's okay if you miss some items, just keep going and
 do the best you can!</p><p>Select "Continue" to begin.</p>",
  choices: ["Continue"],
};


var Show_Instr_OneBack = {
  type: "html-button-response",
  stimulus:
    "<p>In this task you must indicate whether the letter presented is the same
 as the letter presented  <b>one letter</b> before. During the practice session,
 a sound will occur after the letter disappears to let you know if you answered
correctly.  </p><p>Click continue to start the <b>one letter</b> sequence</p>",
  choices: ["Continue"],
};
var Show_Instr_TwoBack = {
  type: "html-button-response",
  stimulus:
    "You are now ready for the next task! Please indicate whether the letter
being presented is the same as the letter presented <b>two letters</b> before by
 pressing the spacebar as quickly as possible. </p><p>Click continue to start
the <b>two letters</b>  sequence.</p>",
  choices: ["Continue"],
};
var Show_Instr_ThreeBack = {
  type: "html-button-response",
  stimulus:
    "<p>You are now ready for the next task! Please indicate whether the letter
 being presented is the same as the letter presented <b>three letters</b> ago by
 pressing the spacebar as quickly as possible. </p><p>Click continue to start
the <b>three letters</b> sequence.</p>",
  choices: ["Continue"],
};

/*
<!-- ****************************** -->
<!-- * Defining random trials * -->
<!-- ****************************** -->
*/
// fill an array with a value; from https://stackoverflow.com/questions/12503146
function fillArray(value, len) {
  var arr = [];
  for (var i = 0; i < len; i++) {
    arr.push(value);
  }
  return arr;
```

```
}
// shuffle the array randomly; from https://stackoverflow.com/questions/2450954
function shuffle(array) {
  var currentIndex = array.length,
    temporaryValue,
    randomIndex;
  // While there remain elements to shuffle ...
  while (0 !== currentIndex) {
    // Pick a remaining element ...
    randomIndex = Math.floor(Math.random() * currentIndex);
    currentIndex -= 1;
    // And swap it with the current element.
    temporaryValue = array[currentIndex];
    array[currentIndex] = array[randomIndex];
    array[randomIndex] = temporaryValue;
  }
  return array;
}
function createTrials(ntarget, ndistractor) {
  var distractors = fillArray("distractor", ndistractor - nLeadingDisttr);
  var headdisttrs = fillArray("distractor", nLeadingDisttr);
  var targets = fillArray("target", ntarget);
  // using concat to concatenat two arrays
  var total = targets.concat(distractors);
  total = shuffle(total);
  //adding nLeadingDisttr distractors at beginning of block
  total = headdisttrs.concat(total);
  return total;
}
// alternate case of the html stimuli
function altercase(ArrayStimuli) {
  var i = 0;
  var result = ArrayStimuli;

  for (i = 0; i < result.length; i++) {
    if (i % 2 == 0) {
      result[i].stimulus = result[i].stimulus.toLowerCase();
    } else {
      result[i].stimulus = result[i].stimulus.toUpperCase();
    }
  }
  return result;
}
// Set array of items according to array of conditions in a n-back sequence.
function createObjectsToRun(condBlock, n) {
  var stimArray = [];
  var i = 0;
  var los = shuffle(ListOfStimuli);
  var pos = n; // position in the shuffled list
  // select the first n items from the shuffled list
  for (i = 0; i < n; i++) {
    stimArray.push({ stimulus: los[i], condition: condBlock[i] });
  }
  for (i = n; i < condBlock.length; i++) {
    if (condBlock[i] === "distractor") {
      // select an item who is different than n before
      while (los[pos] == stimArray[i - n].stimulus) {
        pos = (pos + 1) % nstim;
      }
      stimArray.push({ stimulus: los[pos], condition: condBlock[i] });
      pos = (pos + 1) % nstim;
    } else {
      // create an item that is the same as n before
      stimArray.push({
        stimulus: stimArray[i - n].stimulus,
        condition: condBlock[i],
      });
    }
  }
  console.log("createObjectsToRun returned ", stimArray);
  return altercase(stimArray);
}
// generate dummy practice and full block
var randomtrials = createTrials(nItemsTarget, nItemsTotal - nItemsTarget);
var BackArray = createObjectsToRun(randomtrials, 1);
var randomtrials = createTrials(4, 6);
var PractArray = createObjectsToRun(randomtrials, 1);

/*
<!-- **************************** -->
<!-- * Showing the stimuli * -->
<!-- **************************** -->
*/
var ShowStimulus = {
  type: "html-keyboard-response", // for image, use image-keyboard-response
  stimulus: function () {
    return BackArray[currentTrial].stimulus;
  },
  prompt: function () {
    return(
      "<br>Press the spacebar to indicate if it is the letter shown <b>" +
      currentnback +
      " item(s)</b> previously..."
    );
  },
  choices: [" ", "r"],
  trial_duration: ISIDuration + StimDuration,
  stimulus_duration: StimDuration,
  response_ends_trial: false,
  data: { condition: jsPsych.timelineVariable("condition") },
};

/*
<!-- ******************************** -->
```

```
<!-- * Defining practice blocks * -->
<!-- ********************************* -->
*/
 var Set_PracticeArray = {
   type: "call-function",
   func: function () {
     currentTrial = 0;
     currentnback++;
     randomtrials = createTrials(4, 6);
     BackArray = createObjectsToRun(randomtrials, currentnback);
   },
 };

 function Provide_Feedback(trial_data) {
   if (BackArray[currentTrial].condition == "target") {
     if (trial_data.key_press == 32) {
       snd.play();
     }
   }
   currentTrial += 1;
 }
 var Run_Practice = {
   timeline: [ShowStimulus],
   timeline_variables: PractArray,
   data: { block: "practice-one-back" },
   on_finish: Provide_Feedback,
 };

 var Show_Continue = {
 type: "html-button-response",
 stimulus: "<p>Ready to go again?</p>",
 choices: ["Continue"],
 };

 var Ask_Retry = {
   type: "html-button-response",
   stimulus: "<p>Good practice!</p>",
   choices: ["Continue", "Practice more"],
 }

 var Practice_Loop = {
   timeline: [
     Set_PracticeArray,
     Run_Practice,
     Ask_Retry
   ],
   loop_function: function(data) {
     const vals = data.values();
     return vals[vals.length - 1].button_pressed === '1';
   }
 };
```

```
   /*
  <!-- ******************************** -->
  <!-- * Defining Block OneBack * -->
  <!-- ******************************** -->
  */
// have two specific form of errors in addition to total error
  var mistakeCounter = 0;
  var falsealarmCounter = 0;
  var missCounter = 0;

  var Reset_Counter = {
   type: "call-function",
   func: function () {
    mistakeCounter = 0;
    falsealarmCounter = 0;
    missCounter = 0;
   },
  };
  var Set_BackArray = {
   type: "call-function",
   func: function () {
    currentTrial = 0;

    randomtrials = createTrials(nItemsTarget, nItemsTotal - nItemsTarget);
    BackArray = createObjectsToRun(randomtrials, currentnback);
   },
  };
  function Record_Decision(trial_data) {
   var correct;
   var type;

   if (BackArray[currentTrial].condition == "target") {
     correct = trial_data.key_press == 32; // 32 == space
   } else {
     correct = trial_data.key_press == null;
   }
// keep count of the total number of mistake
   if (correct) {
     jsPsych.data.addDataToLastTrial({ correct: 1 });
   } else {
     jsPsych.data.addDataToLastTrial({ correct: 0 });
     mistakeCounter++;
   }


// record separately hits and false alarms
   if (BackArray[currentTrial].condition == "target") { //hit or miss
    if (correct) {
      jsPsych.data.addDataToLastTrial({ hit: 1 });
      type = "Hit";
    } else {
      jsPsych.data.addDataToLastTrial({ hit: 0 });
```

```
            type = "Miss";
            missCounter++;
        }
      } else { // correct rejection or false alarm
        if (correct) {
            jsPsych.data.addDataToLastTrial({ CR: 1 });
            type = "Correct rejection"
        } else {
            jsPsych.data.addDataToLastTrial({ CR: 0 });
            type = "False alarm";
            falsealarmCounter++;
        }
      }
      currentTrial += 1;

      console.log(
        "Nombre d'erreur ", mistakeCounter, "; current nback: ", currentnback,
        " (type of response: ", type, ")"
      );

    }
// Save scores at the end of three block of a given "currentnback" condition
    var Save_Scores = {
        type: "call-function",
        func: function () {
            Qualtrics.SurveyEngine.setEmbeddedData(
            "nBack".concat(currentnback).concat("FA"), falsealarmCounter.toString()
            );
            Qualtrics.SurveyEngine.setEmbeddedData(
            "nBack".concat(currentnback).concat("MISS"), missCounter.toString()
            );
        },
      }
    var Run_Block_Back = {
      timeline: [ShowStimulus],

      timeline_variables: BackArray,
      data: { block: "block-back" },
      on_finish: Record_Decision,
    };

    /*
   <!-- ************************************* -->
   <!-- * Defining Block Two/ThreeBack * -->
   <!-- ************************************* -->
    */
    // the next blocks are conditional ones. If person made more than
    // 10 mistakes in the previous block, the second will not appear.
    var OneBlock_TwoBack_Run = {
      timeline: [
        Show_Instr_TwoBack,
        Practice_Loop,
        Reset_Counter,

        Set_BackArray,        Show_Continue,
        Run_Block_Back,

        Set_BackArray,
        Show_Continue,
        Run_Block_Back,


        Set_BackArray,
        Show_Continue,
        Run_Block_Back,

        Save_Scores,
      ],
      conditional_function: function () {
        console.log(
          "nombre d'erreur avant OneBlock_TwoBack_Run",
          mistakeCounter
        );
        if (mistakeCounter > MaxError) {
          return false;
        } else {
          return true;
        }
      },
    };
    var OneBlock_ThreeBack_Run = {
      timeline: [
        Show_Instr_ThreeBack,
        Practice_Loop,
        Reset_Counter,

        Set_BackArray,        Show_Continue,
        Run_Block_Back,

        Set_BackArray,
        Show_Continue,
        Run_Block_Back,

        Set_BackArray,
        Show_Continue,
        Run_Block_Back,

        Save_Scores,
      ],
      conditional_function: function () {
        console.log(
          "nombre d'erreur avant OneBlock_ThreeBack_Run",
          mistakeCounter
        );
        if (mistakeCounter > MaxError) {
          return false;
        } else {
          return true;
        }
      },
    };

    /*
    <!-- ****************************** -->
   <!-- * Defining Experiment * -->
   <!-- ****************************** -->
   */
    jsPsych.init({
      timeline: [
        FullScreenOn,
        Show_Instr_OneBack,
        Practice_Loop,
        Reset_Counter,

        Set_BackArray,
        Show_Ready,
        Run_Block_Back,



        Set_BackArray,
        Show_Continue,
        Run_Block_Back,


        Set_BackArray,
        Show_Continue,
        Run_Block_Back,
        Save_Scores,

        OneBlock_TwoBack_Run,
        OneBlock_ThreeBack_Run,
        FullScreenOff,
        Show_Bye,
      ],
      display_element: "display_stage",
      on_finish: function () {
        console.log("Performing on_finish");
        // performing some save here?

        console.log("Saved the results");
        // clear the stage
        // jQuery('display_stage ').remove();
        // jQuery('display_stage_background ').remove();

        // simulate click on Qualtrics "next" button, making use of the Qualtrics JS API
```

```
        qthis.clickNextButton();

        console.log("on_finish says Ok");
      },
    });
  }
});


Qualtrics.SurveyEngine.addOnUnload(function () {
  /*Place your JavaScript here to run when the page is unloaded*/
});
```

Appendix B. HTML script for n-back task

```
<script>console.log("Begining of library uploading...")</script>
<script src="https://rmg2424.github.io/neuromemorylab/CorsiBlockjsPsych/jspsych-6.1.0/jspsych.js"></script>
<script src="https://rmg2424.github.io/neuromemorylab/CorsiBlockjsPsych/jspsych-6.1.0/plugins/jspsych-html-keyboard-response-noerase.js"></script>
<script src="https://rmg2424.github.io/neuromemorylab/CorsiBlockjsPsych/jspsych-6.1.0/plugins/jspsych-html-keyboard-response.js"></script>
<script src="https://rmg2424.github.io/neuromemorylab/CorsiBlockjsPsych/jspsych-6.1.0/plugins/jspsych-audio-button-response.js"></script>
<script src="https://rmg2424.github.io/neuromemorylab/CorsiBlockjsPsych/jspsych-6.1.0/plugins/jspsych-audio-keyboard-response.js"></script>
<script src="https://rmg2424.github.io/neuromemorylab/CorsiBlockjsPsych/jspsych-6.1.0/plugins/jspsych-audio-keyboard-response.js"></script>
<script src="https://rmg2424.github.io/neuromemorylab/CorsiBlockjsPsych/jspsych-6.1.0/plugins/jspsych-html-button-response.js"></script>
<script src="https://rmg2424.github.io/neuromemorylab/CorsiBlockjsPsych/jspsych-6.1.0/plugins/jspsych-fullscreen.js"></script>
<script src="https://rmg2424.github.io/neuromemorylab/CorsiBlockjsPsych/jspsych-6.1.0/plugins/jspsych-call-function.js"></script>
<script>console.log("End of library uploading...")</script>

<link href="https://rmg2424.github.io/neuromemorylab/CorsiBlockjsPsych/jspsych-6.1.0/css/jspsych.css" rel="stylesheet" type="text/css"></link>

<style>
#display_stage_background {
    width: 100vw;
    background-color: white;
    z-index: 10;
}

```

```
#display_stage {
    position: absolute;
    z-index: 11;
    left: 0vw;
    top: 0vh;
    height: 100vh;
    width: 100vw;
    background-color: white;
    box-shadow: 1px 1px 1px #999;
    border-radius: 1px;
    overflow-y: hidden;
    overflow-x: hidden;
}
</style>

<div>
<span style="font-size: 12pt;">
    The experiment is currently loading...
    <br><br>
    If this message appears for more than <span style="color: rgb(255, 0, 0);">
    <b>10 seconds</b></span>,
    please contact <a href="mailto: addyouremailhere">addyouremailhere</a>.
    I apologize for the inconvenience and thank you for your time.
</span>
</div>
```

Open practices

The *Open Material* badge was earned because supplementary material(s) are available on the journal's web site.

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