ARTICLE
Deep versus Shallow Processing: A Learning and Memory Experiment for Asynchronous and Synchronous Online Platforms

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Processing of words can be meaning-based (deep processing) or appearance/sound-based (shallow processing). A simple experiment that can be conducted online, asynchronously or synchronously, demonstrates that the number of words recalled from a list of 24 words read aloud depends on the instructions given to students beforehand. Students in the deep processing group were asked to write 'yes' or 'no' – *is the word likeable/pleasant*, while students in the shallow processing group were asked to write 'yes' or 'no' – *does the word contain an E or G*. After a one-minute delay in which students performed a backward calculation task, they had two minutes to recall as many words as possible from the list. Regardless of how the online experiment was conducted, asynchronously or synchronously, the deep processing group recalled an average of 11-14 words compared to the shallow processing group, which recalled an average of 8-10 words. The deep processing group consistently recalled 3-6 more words on average than the shallow processing group. After debriefing the students about the experiment, the instructor can focus class discussion on topics that include experimental design, methodology, reproducibility, data analysis, as well as using these data as an evidence-based starting point for best learning practices.

Key words: learning and memory experiment; word recall; deep processing; shallow processing; neuroscience experiment; synchronous; asynchronous; remote instruction

It can be challenging for instructors to incorporate experiments in their neuroscience courses due to time constraints, large enrollments, or the need for special equipment or materials. The merit of including active learning approaches in the classroom, however, is clear (Gage, 2019; Ramirez, 2020; Sandrone and Schneider, 2020). Experiments that can be performed quickly, with a large number of students and simple materials, can serve as valuable teaching tools. This is especially true when instructors and students are working together remotely using online platforms (Sandrone and Schneider, 2020).

In this article, I describe a learning and memory experiment examining how levels of processing, deep versus shallow, affect the recall of a list of 24 words (Chew, 2010; McCabe, 2014). Processing of words can be meaning-based (deep processing) or appearance/sound-based (shallow-processing) (Craik, 2002; Craik and Lockhart, 1972; McLeod, 2007). Studies have demonstrated that deep processing leads to recall of more words compared to shallow processing (Chew, 2010; Craik, 2002; Craik and Lockhart, 1972; McCabe, 2014; McLeod, 2007). The levels of processing framework argues that the ability to recall words is related to how they are encoded (Craik, 2002; Ekuni et al, 2011). Deep processing of words activates selective prefrontal and temporal cortical regions while shallowing processing has a different neurobiological profile (Galli, 2014; Rose et al., 2015).

The levels of processing experiment described in this article utilizes students as the subjects and can be performed in 10 minutes (Chew, 2010; McCabe, 2014). For many years I conducted this experiment in-person, but in March 2020 I adapted it for online platforms. First, I will outline the steps of the experiment as performed in-person with instructor and students together in the same classroom.

Next, I will describe how the experiment can be performed using asynchronous and synchronous online platforms. Instructors can use this experiment as the basis for a class discussion of the neurobiological bases of learning and memory or as the basis for more a general discussion of experimental design, methodology or data analysis. I use the results as a starting point for having students consider their own learning and memory (Chew, 2010; McCabe, 2014). In fact, the title for this laboratory in my syllabus is "how best to study" since the students should remain unaware of the intent of the experiment, as they will serve as the experiment's subjects.

METHODS AND RESULTS
Experiment for In-Person Instruction
All students listen to the same list of 24 words read aloud by the instructor (*Figure 1*); what differs are the instructions given to the students beforehand. The instructor passes out a single-page handout to all students, but unbeknownst to the students, the instructor divides the class into two groups, so there are two different handouts. The handouts look similar; both state: "you will hear a list of 24 words, one at a time, read aloud" and have the numbers 1-24 written vertically down the page. The two differing instructions are that students in the deep processing group are asked to write 'yes' or 'no' – *is the word likeable/pleasant*, while students in the shallow processing group are asked to write 'yes' or 'no' – *does the word contain an E or G*. The labels 'deep processing' and 'shallow processing' are not written on the handouts. The instructor asks students to read the instructions quietly to themselves and makes sure everyone is ready before starting. The instructor slowly states each of the 24 words (*Figure 1*) including the corresponding number

(1) Evening	(13) Cold
(2) Country	(14) Love
(3) Salt	(15) Bargain
(4) Easy	(16) War
(5) Peace	(17) Hate
(6) Morning	(18) Wet
(7) Pretty	(19) Rich
(8) Expensive	(20) Nurse
(9) Poor	(21) Pepper
(10) Doctor	(22) Hard
(11) City	(23) Ugly
(12) Dry	(24) Hot

Figure 1. List of 24 words read aloud by the instructor (Chew, 2010; McCabe, 2014).

before each word. The students write 'yes' or 'no' next to each number, 1-24, following the instructions on the top of their handout.

After the final word is read aloud, the instructor asks the students to count backwards by threes from 200 over one minute. Then, the instructor asks the students to write down as many words from the list that they recall, in any order, over two minutes. Afterwards, the instructor asks students to count the number of words recalled, and calls on students, one at a time, to report their data. Therefore, it is important that the instructor keeps track of which of the two handouts the students receive. I do this based on where the students are seated in the classroom. I like to collect data from the students in the shallow processing group first, who recall an average of 7-10 words. Then, I ask the students in the deep processing group, one at a time, to state the number of words recalled; they recall an average of 13-16 words.

The choice to have students report their data orally is convenient and lends some drama. For example, once students in the deep processing group start to report the number of words recalled, this typically produces audible gasps from the students in the shallow processing group. In my experience students do not seem to mind reporting their data in front of their classmates. However, I intentionally do this in an unemotional, equitable way in order to demonstrate that what is important are the data themselves, not who recalled fewer or more words (Ramirez, 2020). Instructors may choose to collect their students' data in ways that are private, such as having them write the number of words recalled on slips of papers and collecting these in a way that keeps the shallow and deep processing groups separate.

Once all the raw data are written on the classroom whiteboard, we calculate the mean number of words recalled, standard deviation, and perform statistical analysis. Next, we discuss the experiment itself. I start by asking a volunteer from each group to read aloud to the class the instructions on the top of their handout. Then, we debrief about the entire experiment, going through the steps of the methods, and also hearing accounts from students who volunteer to share their experiences. Similar to other reports (Chew, 2010; McCabe, 2014), many students in the deep processing group noticed that there were associated pairs of words in the list (*Figure 1*), i.e. "doctor/nurse", "salt/pepper". In turn, these students mentioned that the word-pairs helped them to remember partner words when one word from the pair was easily recalled. Few students in the shallow processing group noticed the presence of word-pairs in the list, consistent with other reports (Chew, 2010; McCabe, 2014).

Experiment for Online Asynchronous Instruction

In Spring 2020, 48 students were emailed a link to a Zoom video of me reading the 24 words aloud; each group of 24 students received a different handout labelled "Group A" and "Group B", corresponding to the shallow and deep processing instructions. Students were asked to read the email instructions and the attached handout carefully. The instructions also included a due date for completing the experiment. Once students were ready, they were instructed to play the Zoom video of me reading the 24 words aloud, asking them to count backwards from 200 by threes (one minute), and asking them to recall as many words as possible, in any order (two minutes).

By email, students sent me their Group (A or B) and the number of words recalled. Out of 48 students, I received data from 44 students. I analyzed these data myself and emailed the students a written summary along with a new Zoom video in which I debriefed the class about the experiment, including background about shallow and deep processing. There was no class discussion. The asynchronous experiment yielded results consistent with those from the in-person experiment: the shallow processing group recalled a mean of 8 words, while the deep processing group recalled a mean of 14 words.

Experiment for Online Synchronous Instruction

In Fall 2020 and Spring 2021, I performed this experiment remotely with four groups of 24 students per group using email and synchronous Zoom meetings.

Immediately prior to the start of our synchronous Zoom classroom, students were emailed one of the two handouts labeled Group A and Group B, with instructions on the top as described in the asynchronous methods. Therefore, since I had emailed the students directly, I knew precisely which students received which handout. In our synchronous Zoom classroom, I waited until all students arrived, then I asked them to open the handout from their email. Students were requested to read the instructions to themselves, and to be prepared to record their responses - 'yes' or 'no' for 24 words - either electronically or on paper. Once everyone was ready, I proceeded by using the same in-person methods: reading aloud the 24 words, one-minute delay with the subtraction calculation task, and two minutes to recall as many words as possible from the list.

To collect the data, I started with the shallow processing group. I called each student by name, one at time, asked them to unmute and to state the number of words recalled. Data were collected in real-time on a Word document that I shared with the class over Zoom. Once I had all the raw data, I told the students that I needed several minutes for data analysis, and I turned off my video and audio. Once completed, I turned my video and audio back on, and I shared the Word document on Zoom with the data analysis. We discussed the experiment synchronously the same way that I described for the in-person methods. The synchronous remote experiment, conducted on four groups of students, yielded data consistent with the in-person and asynchronous experiments: the shallow processing group recalled an average of 8-10 words, while the deep processing group recalled an average of 11-14 words.

DISCUSSION

This experiment demonstrates that when subjects follow instructions asking them to use deep or shallow processing while listening to a list of 24 words it affects the number of words recalled. The experiment is easy and quick to perform and allows the students to serve as the subjects. The results are robust and consistent across in-person and asynchronous/synchronous online platforms. Therefore, instructors should feel confident that the experiment will yield similar data whether conducted in-person or using online platforms.

The choice of how to incorporate this experiment into a course depends on the aim of instructors and how they want to spend their student contact hours. An advantage of using a synchronous platform like Zoom is that the experience and interactions are similar to in-person instruction: everyone is in the same virtual classroom together and the instructor is able to conduct the experiment in real-time. This also has the benefit that data can be collected immediately. In contrast, using asynchronous platforms, raw data collection depends on students submitting them through email or onto an online site, so it could be difficult to ensure full participation. In my one semester experience of using the asynchronous method, four students out of 48 did not submit their data despite sending them email reminders to do so.

On the other hand, instructors might prefer to utilize asynchronous platforms to conduct the experiment, thereby leaving student contact hours available for other activities such as data analysis and class discussion. Asynchronous platforms also allow the students to perform the experiment according to their own schedules, perhaps in a more relaxed way. However, when using asynchronous methods instructors need to make certain that the students have sufficient instructions to conduct the experiment on their own. To facilitate this, I provided detailed written instructions in my email to the students. I repeated these orally at the beginning of my video, and then told the students to pause the video if they were not yet ready to begin the experiment. In turn, my students did not report any issues with misunderstanding or being uncertain about how to perform the experiment. That said, I had no way of knowing whether students did not “cheat” and write down the words as I said them aloud. However, since these data are indistinguishable from those using in-person or synchronous online methods, I feel confident that the majority of students must have followed the instructions appropriately. If instructors plan to use an asynchronous online method, they may want to state explicitly that students should not write down any of the words while they are listening to the list.

The use of simple experiments in the classroom gives students opportunities to explore experimental design, reproducibility, data analysis and interpretation (Baker, 2016; Carter et al., 2017; Fry, 2014; Pollack, 2010). Certainly, an experiment examining the effect of deep versus shallow processing on word recall fits well within courses (or sections of courses) about learning and memory, especially regarding the encoding of declarative memory (Craik, 2002; Ekuni et al, 2011; Galli, 2014; Rose et al., 2015). Moreover, the ability to conduct this experiment quickly, in-person or online, gives instructors the flexibility to utilize it to suit their own needs. In fact, my own thinking has shifted recently about when and how I use this experiment in my Neurobiology course. For years it was the last experiment of the semester, corresponding to the section of the course about learning and memory. Beginning in Fall 2020, it is now the first experiment. My rationale for this change is several-fold. It takes advantage of student enthusiasm at the beginning of the semester and allows everyone to participate as subjects and to have their voices heard, even if only to report their data aloud. In addition, the results provide compelling evidence for students to examine their own learning practices. This is something that I highlight during class discussion and that I hope the students apply and carry forward in their education and lives.

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