ARTICLES

Poppy Seed Consumption and Oral Fluid Opioids Detection: A Classroom Demonstration of Psychopharmacological Concepts

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https://doi.org/10.59390/JWNQ5957

Psychopharmacological concepts such as pharmacokinetics, pharmacodynamics and drug interactions can be difficult to illustrate within the college classroom. In this demonstration, students consume poppy seed-containing food items, assess opioid content in their oral fluid using commercial drug test kits, and relate the findings to learned materials, its real-life applications, and relevant societal implications. This demonstration can clarify processes such as drug absorption, distribution, metabolism, and excretion (ADME), broaden the review of information relevant to opioids mechanisms of action, and facilitate the discussion of topics such as drug abuse, dependence, and addiction, as well as drug development, testing, policy, and enforcement. Instructors can employ different experimental designs, create dose-dependent/timeline detection plots, or allow students to construct their own experiments, assessing possible mediators of opioid detection. The demonstration can also be utilized to discuss scientific myths, truths, data misinterpretation and misrepresentation. Several optional protocols are provided, required materials are indicated, and discussion points are suggested.

Key words: psychopharmacology; opioids; poppy seeds; drug testing; oral fluid

Psychopharmacology (sometimes referred to as *drugs and behavior*, *drugs and society*, etc.) is an undergraduate course which aims to introduce college students with various drug classes, provide them with factual knowledge (e.g., drugs' mechanisms of action and biobehavioral effects), and facilitate their ability to make informed drug-related decisions and adopt a safe and healthy lifestyle.

Despite its applicable nature, the course's content can be perceived as challenging. Enrolled students are typically required to memorize anatomical pathways, neurotransmitter systems, receptor subtypes and drugs' brand/generic names. They need to distinguish agonists from antagonists, compare routes of drug administration, review metabolizing enzymes, and calculate drugs' half-lives. They are expected to understand a variety of drug interactions, remember long lists of possible side effects, and relate all these concepts to its real-life applications.

One of the course's most intricate components is the topic of pharmacokinetics. For a drug to bind with a molecular target (and yield physiological, biochemical, and behavioral effects), it must first be absorbed into the individual's bloodstream and undergo distribution across a variety of biological membranes. For the drug's effects to cease, metabolic and/or excretion processes must inactivate the drug and eliminate it from one's body. The drug's absorption, distribution, metabolism, and excretion (abbreviated ADME or LADME, to include the drugs' liberation from its dosage form), can be exemplified using an accessible, cost-effective, and engaging classroom demonstration. As detailed in this article, the demonstration utilizes poppy seeds and oral fluid test drug kits and is tailored to the topic of opioids drugs.

Opioids belong to the class of drugs known as narcotic analgesics. They reduce pain without causing unconsciousness, promote sleep, and produce a sense of relaxation, well-being, and euphoria. Additional side effects include decreased blood pressure, hypothermia, constipation, respiratory depression, and at high doses - coma and death. Exogenous opioids, such as heroin, morphine, codeine, or methadone bind with μ (mu), δ (delta), and κ (kappa) receptor subtypes, endogenously activated by the neuropeptides endomorphine, endorphin, enkephalin, and dynorphin (Meyer and Quenzer, 2019).

Even though the medicinal properties of naturally occurring opioids (opiates) such as morphine and heroin have been known for centuries, a startling rate of opioid-related overdose deaths over the last few decades has prompted the reexamination of opioid use for pain management. In 2019, a total of 49,860 (70.6% of drug overdose deaths) involved opioids, and in 2020 this rate increased to 68,630, 74.8% of all drug overdose deaths (Centers for Disease Control and Prevention, 2022). This escalation, often referred to as the opioid crisis/epidemic, is fueled by trends in the manufacturing, marketing, and availability of various opioids (Lyden and Binswanger, 2019; Meyer and Quenzer, 2019). For instance, in 1995, the extended-release opioid oxycodone was approved for use by the Food and Drug Administration and marketed to physicians as a safe and effective opioid pain reliever (Lyden and Binswanger, 2019). Respectively, an 866% increase in retail sales of oxycodone was registered between 1997 and 2007 (Kibaly et al., 2021). Oxycontin (a delayed-release formulation of oxycodone which can be crushed to result in fast absorption) was introduced in 1996 and soon became relatively accessible with fake or tempered prescriptions (Meyer and Quenzer, 2019). The

recent surge of illicitly manufactured fentanyl and its analogues has contributed to the problem (Han et al., 2019).

Students in the psychopharmacology classroom may be familiar with the opioid epidemic but the fact that the opioid opium is an extract of the same plant that produces poppy seeds usually surprises them. Opium is prepared when the milky juice taken from the seed capsule of the opium poppy plant (*Papaver somniferum*) just before its ripening is dried and powdered (Meyer and Quenzer, 2019). Mature poppy seeds used as baking ingredients or to produce edible oils do not contain opium, but they can become contaminated with it because of pest damage and during harvesting (Knutsen et al., 2018; Lachenmeier et al., 2010). Depending on seed origin and method of processing, varying levels of opium alkaloids (principally morphine but also codeine, thebaine, oripavine, papaverine, and noscapine) can be detected in poppy seeds (Knutsen et al., 2018; Lachenmeier et al., 2010; Samano et al., 2015).

The need to distinguish between dietary poppy seed ingestion and legitimate/illegitimate use of opioids is of importance, given that individuals performing safety-sensitive duties (Samano et al., 2015), athletes (Thevis et al., 2003), and military personnel (Garamone, 2023) are routinely tested for drug use and abuse. To minimize the number of positive opioid tests resulting from poppy seed consumption [e.g., the "poppy seed defense" (Meadway et al., 1998)], in November of 1998, the Substance Abuse and Mental Health Services Administration (SAMHSA) has raised the federally mandated cutoff concentration for morphine and codeine in urine from 300 ng/mL to 2,000 ng/mL (Fraser and Worth, 1999). Although the change was estimated to reduce confirmed-positive rates for codeine and morphine by more than 300% (Fraser and Worth, 1999), data shows that the ingestion of poppy seeds can still result in urinary concentrations which exceeds this threshold (Fraser and Worth, 1999; Lachenmeier et al., 2010; Rohrig and Moore, 2003; Samano et al., 2015; Smith et al, 2014;).

While opioid drug testing can be performed using blood/serum, sweat or hair samples (for review see Lachenmeier et al., 2010), urine analysis has historically been used in federally regulated programs and in workplace settings (Samano et al., 2015). Oral fluid detection is another suitable alternative, given that it is easy to collect, the collection is non-intrusive/invasive, the samples are difficult to adulterate or substitute, and since it provides a detection window which better reflects potential impairment (Samano et al., 2015). For codeine/morphine, SAMHSA's "Mandatory Guidelines for Federal Workplace Drug Testing Programs using Oral Fluid (OFMG)" has set a 30 ng/mL cutoff concentration for the initial test and a 15 ng/mL cutoff concentration for the confirmatory test (Health and Human Services, Substance Abuse and Mental Health Servies Administration, 2015). Using Gas chromatography/mass spectrometry (GC/MS) technology, Rohrig and Moore (2003) found that morphine concentration in their participants' oral fluid peaked 15 minutes post-poppy seed ingestion (reaching a range of 120-205 ng/ml) and remained above the cutoff for one hour. Using both GC/MS and enzyme immunoassay methodologies, Samano et al. (2015) confirmed that morphine and codeine levels in oral fluid peak 15 minutes after the ingestion of poppy seeds and remain above cutoff for 15-30 minutes. Importantly, Samano et al., (2015) also found that the likelihood of opioid detection was higher after the consumption of raw (compared to baked) poppy seeds.

Currently, a variety of oral fluid drug test kits for opioid use are available for public purchase. Although accurate detection requires that test results are lab-confirmed, these products can be easily integrated into the educational setting. As described below, instructors can obtain poppy seed-containing food items, assign their students into poppy seed-consuming or control conditions, utilize oral fluid drug test kits for opioids detection, and explain the findings in the context of learned topics.

LEARNING OBJECTIVES

This demonstration will: (1) facilitate the comprehension of psychopharmacological concepts such as pharmacokinetics and pharmacodynamics through a hands-on exploration of these topics; (2) enhance students' familiarity with opioid drugs, the opioid epidemic, and opioid drug testing; (3) yield a better understanding of the relevance of psychopharmacological concepts to our every day's lives. These objectives are aligned with the curricular recommendations and core competencies identified as critical for effective undergraduate neuroscience education (Wiertelak et al., 2018; Ramirez, 2020).

I use this demonstration in a few of my courses. In my upper level 'Psychopharmacology' course (PSYC 404), I utilize the demonstration to exemplify pharmacokinetic processes (ADME) and explain the pharmacodynamic mechanisms through which opioid drugs affect different brain areas/pathways to yield a variety of biobehavioral effects. I revisit it when I introduce students to the topic of drug abuse, dependence, and addiction, and when I review practices which involve drug development, policy, and enforcement. I also explain how the oral fluid drug kit assay works and invite students to examine different variables which can modulate the likelihood of drug detection in oral fluid (including the topic of pharmacogenetics in the discussion). In my upper level 'Biopsychology' course (PSYC 314), I use the demonstration in the context of pharmacokinetic and pharmacodynamic mechanisms such as routes of drug administration, therapeutic index, agonistic versus antagonistic action, and drugs' beneficial versus toxic effects. I discuss the mechanism by which the oral fluid drug kit assay operates and describe other methods of drug testing. I sometimes use the demonstration in my lower level 'Introduction to Psychology' course (PSYC 101) to initiate an exploration of psychological myths, truths, and misconceptions (e.g., can an individual test positive for opioids following the consumption of a poppy seed muffin?), and to introduce students to the use of the scientific method in an inquiry-driven context (e.g., would data support the hypothesis that an individual can, in fact, test positive for opioids following the consumption of a poppy seed muffin?). Finally, in my one-week, high school students-oriented "Psychology and Neuroscience" summer STEM academy (described in Flaisher-Grinberg, 2022), I use the demonstration as a fun and engaging primer to the fields of

neuroscience and psychopharmacology.

MATERIALS AND METHODS

The materials required for this demonstration include commercial oral fluid drug test kits, poppy seeds or poppy seed-containing food items, a control condition, and a plan (see an optional handout provided as a supplement). Some available test kits include STATSWAB, Oratect, Oral Cube, T-Cube (which I previously used), as well as Prime Screen, T-square, InstaCube, etc. The cost per test kit can range from $2-10 per kit, depending on the kit's number of panels (number of tested drugs), source (e.g., amazon, eBay, the manufacturer's website), and on the number of purchased test kits (a bulk order is recommended, bearing in mind that the kits have an expiration date).

When purchasing oral fluid drug test kits, it is important to notice that some kits utilize lower cutoffs (e.g., 10 ng/ml) compared to the more commonly used 40 ng/ml cutoff, and that for different kits, the oral fluid collection/window of detection timeline may vary. Also, while some kits detect general opioid usage, some detect distinct opioid targets (e.g., morphine, morphine/codeine). Importantly, all oral fluid kits that I have ever used assess for more than a single drug (commonly 4-12 panels), detecting compounds such as amphetamine, methamphetamine, cocaine, benzodiazepines, barbiturates, phencyclidine, ketamine, marijuana/cannabinoids/THC, as well as prescription opioids such as oxycodone, buprenorphine, methadone, etc. Purchasing a kit with a low-number panel is predicted to minimize cost and reduce the likelihood of collecting unintended information.

Poppy seed-containing food items can be purchased or baked, depending on regional availability and/or the instructor's creativity. In the past, I have purchased bagels, rolls, muffins, kolaches, and Hamantaschen (baked products with poppy seed filling) from local vendors (including the institution's dining center), for less than $1 per item. Occasionally, I choose to bake poppy seed muffins, a strategy that allows me some control of poppy seed quantities in each item. I have never tried using non-baked poppy seeds, given anecdotal reports which describe the ingestion of raw poppy seeds as unpleasant or unpalatable (for review, see Samano et al., 2015). An instructor who wishes to integrate raw poppy seeds into future demonstrations may choose a dose lower than 15 g, a quantity indicated to be close to the maximum tolerable limit of ingestion (Samano et al., 2015).

When purchasing/baking poppy seed-containing food items, one should consider the fact that opioid detection in oral fluid may depend on the seeds' origin and processing. Rohrig and Moore (2003) found that detection was influenced not only by the consumed quantity but also by the poppy seeds' preparation (bagels versus a commercial jar) and possibly by the device used to collect the samples. Samano et al., (2015) demonstrated differential detection ratios when participants consumed raw versus processed poppy seeds and hypothesized that the rinsing of oral cavity/brushing post-poppy seed consumption may affect test results. Others demonstrated that washing, soaking, grinding, and baking affect detected opiate content (for review, see Lachenmeier et al., 2010). Since this factor may generate results that are harder to predict or somewhat inconsistent, it is recommended that the instructor test their chosen poppy seed source ahead of the demonstration.

Procedure

An Experimental Versus Control Conditions Design

An example handout I use for one of my courses is provided as a supplement. This design requires that students self-assign into one of two conditions: an experimental or a control group. While the experimental group consumes a poppy seed-containing food item, the control condition consumes an item devoid of poppy seeds (e.g., a chocolate-chip muffin). Typically, once an introduction to the demonstration is provided, students are requested to consume the food item that matches their experimental condition. A time limit of 2-3 minutes is allocated for the item's consumption, to somewhat synchronize absorption and metabolic process among participants. Given that morphine/codeine concentration in oral fluid peaks 15

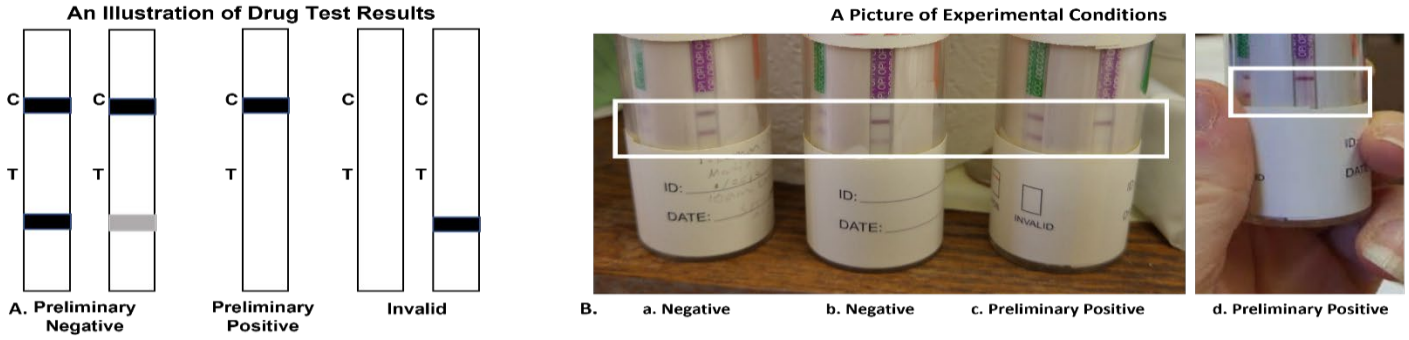

Figure 1. (A) Results illustration. On the left, 'negative' results are shown: two lines appear; one in the control region (C), and another in the test line (T). Although the test line's shade of color may vary, a visible line (even faint) indicates 'negative' results. In the middle, 'positive' results are shown: one color line appears in the control region and no line appears in the test region (T). On the right, 'invalid' results are shown: the control line fails to appear. *(B)* A picture of an optional experimental condition: (a) Negative detection (pre-poppy seed consumption); (b) Negative detection (faint test line 10 minutes post-poppy seed consumption); (c) Preliminary positive detection (absent test line 20 minutes post-poppy seed consumption); (d) Preliminary positive detection. Results close-up.

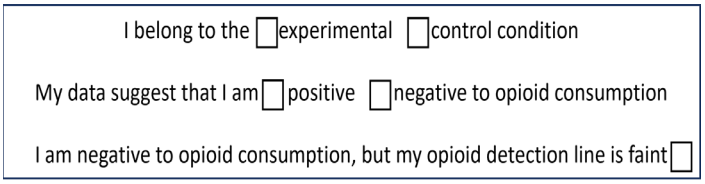

Figure 2. An anonymous note used to report findings.

	Number of participants who tested 'positive'	Number of participants who tested 'negative'
Experimental group		
Control Group		

Table 1. A table representing the class's collective findings.

minutes post-poppy seed ingestion and remains above cutoff for about an hour (Rohrig and Moore, 2003; Samano et al., 2015), it is advised that at least 15 minutes pass prior to oral fluid opioid detection. I usually use a 20-minute interval between consumption and detection, although a 45-minute interval has yielded positive opioids detection in the past. During the interval, I resume teaching and/or ask the students to complete a demonstration-associated task. To improve accurate detection ratios, students are asked in advance to avoid eating or drinking anything but water for at least an hour before (and throughout) the demonstration.

Notably, students who play sports / work in a job that conducts random drug tests are requested to join the control condition. Students who suffer from food allergies (gluten/dairy-free items can be prepared in advance), take medications that interact with food, or don't want to eat the item, are also requested to join the control group. Students who consumed poppy seeds in any form a few hours prior to the demonstration are asked to indicate that (in my 9 years of utilizing the demonstration, this has only happened once). Though I never asked students to indicate if they are prescribed with opioid drugs, such information has the potential to contribute to both the demonstration and to later class discussion. Thus, the instructor may choose to collect this information in future demonstrations, forming a positive control condition.

Once the time interval between consumption and detection has ended, students are requested to collect oral fluid using provided drug test kits. While the method and timing of collection may vary depending on the chosen brand, kits typically include a collection sponge and students are asked to swab all areas of their mouth (left and right cheeks, top and bottom of tongue) for a few minutes (making sure that the collector is soaked with oral fluid and has no "hard" spots are left). Since most oral fluid test kits operate as lateral flow chromatographic immunoassays, placing the collection sponge into the test vial will cause the oral fluid to migrate upwards by capillary action. The test vial contains membrane strips that are coated with drug-specific antibodies on the test (T) line and control antibodies at the control (C) line, both conjugated to colored microspheres (Koczula and Gallotta, 2016). Based on the principle of competitive binding, a drug that is absent or is present in the oral fluid below its cut-off concentration will not saturate the binding sites of its specific antibody. The antibody will then react with the color conjugate and a visible colored line will show up in the test line region of the specific drug strip. A drug that is present above the cut-off concentration will saturate all the binding sites of the antibody and a colored line **will not appear** in the test line region of the specific drug strip. A faint colored line in the in the test line region is considered negative. Serving as a procedural control, a colored line is set to always appear at the control line region (C). The presence of the control line (C) suggests that proper volume of specimen has been added and membrane wicking has occurred. The absence of the control line designates the test invalid. The lines usually take 2-3 minutes to appear.

To summarize, two colored lines in the (T) and (C) regions (even if the T line is faint), render the test negative, a single line in the (C) region renders it (preliminary) positive, and a single line in the (T) region renders it invalid (Figure 1A). Importantly, this is the opposite of what is seen with several other commercial test kits (e.g., home COVID or pregnancy test kits), in which the appearance of a second colored line renders the test positive.

To demonstrate the importance of data privacy, students may be asked to report their findings via an anonymous note (Figure 2), passed to the instructor for processing. The instructor may also choose to present the class's collective findings as seen in Table 1.

The advantage of the experimental versus control condition design is that only one test kit per student is used and thus it is relatively cheap. The design can be utilized in small and large classrooms and given that it only requires two experimental conditions, it is easy to prepare. It fits within a 50- or a 75-minute class session and can even be performed remotely (see below).

A Before-After Experimental Design

This design requires that students utilize the test kits prior to poppy seeds/control item consumption and 15-45 minutes thereafter. The advantage of the design is that even though many students test negative for opioids after poppy seed consumption, the colored test line in the 'after' condition often appear faint compared to the 'before' condition, signaling that a low level of opioids is present in the sample. Also, while the experimental versus control conditions design described above has the potential to yield false positive results (depending on students' food/medications consumption prior to the demonstration), this design pre-test, and thus mitigates, this possibility. A direct comparison within and between participants can facilitate a discussion relevant to the accuracy of drug testing and generate initial hypotheses as to the quantity of poppy seeds that must be consumed for one to test positive. The clear disadvantage of this design is the double-up of necessary funds.

Dose-Dependent and Timeline Designs

Additional protocols employ various poppy seed quantities or utilize multiple time-intervals between poppy seed consumption and detection, to demonstrate related learned concepts. For instance, the instructor may choose to divide the experimental group into conditions which consume gradually higher quantities of poppy seeds. This can be done by securing many poppy seed-containing food items and assessing oral fluid for students who consumed an increasing number of items (e.g., one, two or three items). Alternatively, the instructor may choose to purchase/bake food items with different poppy seed concentrations. Again, it is recommended that the instructor test the chosen poppy seed source prior to the demonstration. To generate a timeline detection plot, the instructor may choose to create a few experimental-control pairs, testing students' oral fluid at various time intervals following consumption (e.g., 10, 20 or 40-minutes post-consumption, see an example in Figure 1B). If the instructor is willing to coordinate such manipulations, some students can be tested after longer intervals (e.g., 3, 6 or 24 hours).

The advantages of these designs are that they may be appropriate for large classrooms and can demonstrate complex topics. The disadvantages include the fact that these designs require more preparation and possibly a higher number of food items. The collection and analysis of results for these designs may also be more time-consuming.

Other Applications

Depending on the instructor's interests, resources, and class size/structure, several stimulating variations to this demonstration can be implemented in high-level courses (e.g., 4xx level). For instance, once the topic has been introduced and the demonstration has been conducted, students can be invited to generate their own complementary experimental designs; they can select specific research questions, examine published literature to form educated hypotheses, choose proper experimental methodologies, collect and analyze results, reach conclusions, and even practice scientific writing. As examples, students may choose to assess whether poppy seed detection is different across genders, ages, athletic status, in participants who consumed food prior to the demonstration, in participants who regularly consume poppy seeds, etc. This design can be 'stretched' across multiple class sessions or be utilized in very large classrooms, where many participants are available. It can be constructed as an individual, group or class project, or shaped into a faculty-guided independent study/research project. As such, students can design longitudinal studies, add participants and mediating factors, supplement the findings with behavioral assessments (e.g., pain sensitivity test), or add questionnaires/interviews (e.g., personal beliefs).

Depending on available funds, time and expertise, this demonstration can be expanded to target additional theoretical and methodological territories. For instance, the findings collected using oral fluid test kits can be compared to findings collected using urine analysis test kits, or samples can be analyzed using GC/MS (Rohrig & Moore, 2003; Samano et al, 2015), gas/liquid chromatography–tandem MS (GC/MS/MS or LC/MS/MS), or enzyme linked immunosorbent (ELISA) assays (Heltsley et al., 2011). A discrepancy in detection when different methods are used can be developed into an interesting class discussion.

Depending on the course's delivery modality, this demonstration can also be utilized within remote instruction. In the spring of 2020 (during the COVID pandemic), Saint Francis University (SFU) students returned to campus, but to avoid exposure to bodily fluids during class time, I asked students to pick up their test kits and individually wrapped food items ahead of class time and performed the demonstration via zoom. Since the demonstration was well-perceived by students when conducted in this fashion, it is envisioned that with some preparation (e.g., test kits and food items can be sent to students' homes in advance), the demonstration can be integrated into remote-settings courses.

RESULTS

When the demonstration is implemented, in line with the fact that the consumption of poppy seeds can indeed lead to positive results in oral fluid testing (Rohrig and Moore, 2003; Samano et al., 2015), between 20-90% of the participants who consume poppy seeds test positive for opioids (depending on the seeds' source and preparation). In addition, a significant number of participants commonly test negative but detect a faint test line, suggesting that sub-threshold opioid content is available in their bodies.

In two sections of my spring 2023 PSYC 314 "Biopsychology" course the demonstration included poppy seed and chocolate-chip muffins and an experimental versus control design. The protocol was approved by SFU's Institutional Review Board (protocol number 2021-25-SFU). As seen in Figure 3A, several students enrolled in the course indeed tested positive for opioid following the consumption of poppy seed-containing muffins. Specifically, all students in the control group (14 students in each session) tested

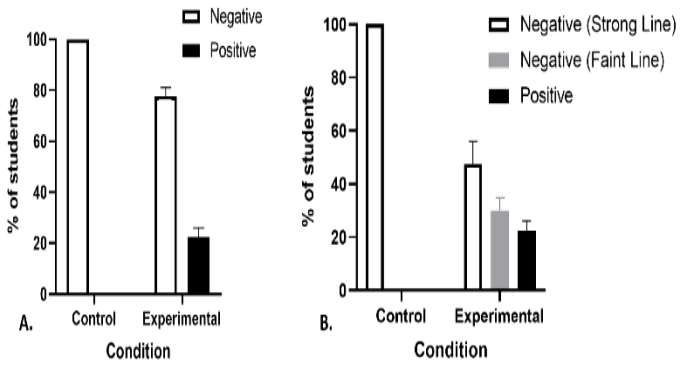

Figure 3. (A) Percentage of students who tested negative/positive for opioids across the control/experimental conditions, and (B) when the strength of the colored line in the test region of the kit was divided into a strong versus faint line. Data collected in two sessions of the spring 2023 PSYC 314 "Biopsychology" course, in which students in the experimental condition consumed poppy seeds muffins, and students in the control condition consumed chocolate chip muffins. Results combined.

negative for opioids. Of the students in the experimental group (15 students in session 1 and 12 students in session 2), 3 students tested positive in the first session (20%) and 3 students tested positive in the second session (25%). When the strength of the colored line in the test region was taken into account (Figure 3B), 4 students in session 1 (26.5% of the experimental condition or 33.5% of the experimental participants who tested negative for opioids) detected a faint opioid line. In similarity, 3 students in session 2, (25% of the experimental condition or 33.5% of the experimental participants who tested negative for opioids) detected a faint opioid line.

The potential benefits of the demonstration can be seen at the level of students' comprehension of learned psychopharmacological concepts, familiarity with opioid-specific related topics, ability to recognize the relevance of these materials to their every day's lives, and level of enjoyment while engaging with the demonstration. This notion is supported by a few lines of assessments.

First, one of the exams in the course included six questions directly related to the demonstration. Specifically, six out of 45 exam questions assessed students' comprehension of psychopharmacological and opioid-related topics which were integrated into the demonstration. While the students' mean grade in the exam was 82% (with grades ranging from 50%-100%), a mean grade of 93% was registered across the six demonstration-related questions (with a range of 86%-98%).

Second, in comparison to the two other demonstrations integrated into the course (a sheep brain dissection and a mouse brain histological examination), students' completion of the handout associated with the demonstration (see the supplement) yielded higher grades. Specifically, while the mean grade for the handout associated with the sheep brain dissection was 13 out of 15 points (86.6%), and the mean grade for the handout associated with the mice brain histological examination was 12 points (80%), the mean grade for the poppy seed/psychopharmacology demonstration-handout was 14 points (93.5%).

Third, anonymous reflections collected via institutionally delivered assessment forms and instructor-constructed surveys indicated that students find the demonstration to be educational, beneficial, and fun. For instance, students comment that: "I really enjoyed the poppy seed demo and I feel that it helped me understand the class material better"; "I would say that I genuinely learned things from the poppy seed activity that I can apply to real life"; "The poppy seed demonstration that we did was very informative and relevant to the topics covered in class. Having hands on opportunities in psychology classes are rare, so that helped a lot"; "The time when we ate poppy seed muffins and tested our saliva is one that I will never forget, it was like nothing I have done before"; "I really liked the activity where we ate poppy seed muffins and took a test. I thought that was super cool and I also think that, if possible, you should keep doing that in future classes".

Informal observations about students' response to the demonstration are in line with their reflections. Typically, some of the students are familiar with the "poppy seed defense" theory, some have never heard of it, and some have never even consumed poppy seeds prior to the demonstration. Those familiar with it tend to believe that it's a pure myth, an urban legend or just plain bogus. Some mention that they have heard that it is an invalid theory from their family/friends and are quite skeptical about the plausibility that it is correct. During the demonstration, students are usually eager for the detection interval to pass, impatiently chatting about the possible implications of the findings. Upon the collection of the results, students react with pure surprise to the fact that some of their classmates have indeed tested positive for opioids, and that some of their classmates have detected a faint line in their test kits. They laugh, take pictures of their test kits, and ask if they can share the information with others outside the classroom. This is usually the beginning of a lively discussion, ignited by students' questions. Commonly, the conversation explores the hypothetical quantity of poppy seeds that should be consumed for faint-line tests to turn positive, the timeline through which individuals who tested positive should expect their results to remain as such, factors which may increase or decrease the chances of an individual to test positive, or the immediate implications of the findings to students' lives. For instance, students often wonder why information about the possibility of testing positive for opioids following the consumption of poppy seed-containing food items is not widely known to the public. They ask if this knowledge can be beneficial to individuals who play sports / work in a job that conducts random drug tests, to individuals who are prescribed with opioids, or to individuals who use them illicitly). Students also wonder if the consumption of large amounts of poppy seeds can cause opioid-related effects (e.g., pain reduction), if other drug tests can be affected by variables such as food or medications, and what can be done to improve testing accuracy.

DISCUSSION

The described demonstration has the capacity to capture participants' attention, expand their psychopharmacological comprehension and engage them in scientific exploration. In community-oriented contexts (e.g., Brain Awareness Week lectures/presentations), it can be used as a fun and intriguing introduction to psychology, biology, neuroscience, or STEM, acting to facilitate participants' educational interests and career development. Utilized within the framework of scientific misconception, misinterpretation, and misrepresentation, it can also be leveraged towards the improvement of the dialogue between academia and the public (Illes et al., 2010).

The fact that the demonstration was found to improve students' performance in exam-related questions and handouts completion, and to generate a sense of joy and satisfaction, supports the suggestion that the demonstration is of educational benefit. Such findings were seen in previous iterations of the PSYC 314 "Biopsychology" course, as well as in other courses (PSYC 404 "Psychopharmacology" and PSYC 101 "Introduction to Psychology") which were not directly assessed. While several applications to the demonstration are described above, it has the potential to fit additional contexts, providing a variety of pedagogical gains.

The findings that the data presented above includes a relatively low number of students tested positive for opioids may seem, on the surface, to render the demonstration ineffective. The combined number of positive-tested and faint-line tested students, however, accumulates to almost 50% of participants, which is a significant number. Addressing the possible meaning of a faint test line in class (e.g., detectable yet sub-threshold systemic opioid levels), allows students to easily understand the probable implication of their findings (e.g., increasing the quantity of consumed poppy seeds, or decreasing the test kit's cutoff, may lead to positive test results). Although the seeds' origin, quantity and processing can create variations in detection ratio (Lachenmeier et al., 2010; Rohrig and Moore, 2003; Samano et al., 2015; Shetge, 2020), I have never experienced a demonstration in which none of the experimental participants tested positive. In addition, since positive results have yet to be detected in any of the control condition participants, it seems less likely that positive results in the experimental condition can be attributed to an alternative explanation (such as the consumption of opioid-containing medications prior to the demonstration).

There are a few recommendations associated with the delivery of this demonstration. First, the demonstration has the potential to be misconceived by parents or institutions. It is thus of immense importance to explain the theoretical framework of the demonstration to all participants, and if applicable, to institutional supervisors. It is especially recommended that the instructor clarifies that those who have tested positive using the oral fluid test kits did not "fail a drug test" but rather "successfully demonstrated a learned concept". Although in my nine years of using the demonstration I have never run into a single complaint/restriction, it may be useful to seek permission to conduct this demonstration ahead of time. In this respect, it is recommended that students who may undergo drug testing (e.g., athletes) are assigned into the control condition. The instructor may also choose to indicate that research shows that following the consumption of poppy seeds, opioid levels remain high for a longer period in urine compared to oral fluid (Rohrig and Moore, 2003; Samano et al., 2015). Although I have never used urine drug test kits in the classroom, these differences make for a great conversational topic, which can be extended into an introduction to lab-based technologies (e.g., ELISA, GC/MS, etc.). Given reports of drug cross-reactivity affecting test results [e.g., diphenhydramine leading to positive urine methadone detection (Rogers et al., 2010), or the sugar substitute Stevia leading to positive urine Buprenorphine detection (Plattner et al., 2021)], instructors may also choose to discuss possible pitfalls to the testing method, comparing concepts such as false positive/negative results.

Second, the demonstration may require a large number of oral fluid test kits (depending on class size and experimental design) and most kits have a relatively proximate expiration date. It is thus recommended that a budget for the demonstration is secured. Since expired kits can sometimes be found at reduced prices, instructors may choose to explain to students what expired drugs are, the possible implications of using an expired drug/test kit, or even compare expired to non-expired kits as an experimental condition.

To summarize, despite the preparations required to conduct the demonstration, it has the potential to yield beneficial learning outcomes, exemplifying various theoretical concepts, combined with important 'real-life' applications. It is my hope that fellow instructors may find it useful and choose to integrate it into their lessons.

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Received June 29, 2023; revised September 13, 2023; accepted September 15, 2023

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This demonstration was generated by Dr. Richard A. Deyo, Professor of Psychology at Winona State University, MN. Financial support for this project was provided by SFU's "Faculty Development" and "Excellence in Education" grants to the author. I wish to thank the students in my spring 2023 PSYC 314 "Biopsychology" course for their participation and feedback on this classroom demonstration.

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