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ARTICLE
The Digital Microscope: A Tool for Teaching Laboratory Skills in Distance Learning Courses

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The majority of undergraduate students studying for a science degree will at some point carry out experiments in a laboratory setting, thus developing their practical skills and understanding of experimental principles. For distance learning students, there is no laboratory setting available for them to complete such work and as such there is a risk that they will lack these key skills. The Open University has developed a computerized tool, in the form of a Digital Microscope, to allow students to collect data to investigate the effects of drugs of abuse on different regions of the rat brain.

Small groups of students were set a specific hypothesis to investigate, in this instance students were looking at the differential effects of cocaine and amphetamine on the caudate putamen. Using the microscope students counted the number of Fos positive cells in the caudate putamen to contribute to a group data set. Tutors collated the data from all students in the group and returned the full set to them for analysis and interpretation.

In order to evaluate the Digital Microscope we compared student data with data collected by a tutor on the course and obtained feedback questionnaires from students and tutors. We found that while student counts were substantially higher than those made by a tutor, the relationships between experimental groups were preserved. Furthermore, the majority of students and tutors felt that using the microscope had provided useful experience of a number of key practical skills including obtaining and collating data, and the potential areas of error in experiments. Both tutors and students felt that the provision of the microscope had added value to the course. In light of these positive ratings, we feel that this unique tool is useful, not only in distance learning, but also in traditional universities where animal experimentation is limited.

Key words: digital microscope, Fos, laboratory skills, amphetamine, cocaine.

Virtually all named undergraduate degrees in the sciences require the student to complete a practical or experimental element. The facilities required to complete an experiment are often available within the teaching departments with students conducting both laboratory bench work and, as is becoming more common, experiments with the aid of ICT. However, this aspect of degree courses is much harder to achieve in a distance learning environment where the majority of students will work from home for the entire duration of their degree.

At the Open University, students studying for degrees in Life Sciences, Natural Sciences or Psychology can study specified modules in neuroscience. In particular, a level two course entitled Biological Psychology: Exploring the Brain is compulsory for those wishing to have a psychology degree eligible for professional accreditation, currently obtained by around 900 graduates per year at the Open University. Biological Psychology aims to provide an integrated, interdisciplinary approach to the brain, to the behavioural and psychological sciences, and to the relationships between them. Students are advised that they will learn how to formulate hypotheses; plan and carry out investigations; and analyze the resulting data.

Students studying for the above named degrees have between two and four weeks of practical experimental experience at Open University residential schools, but there is no provision for laboratory experience specifically related to the neurosciences. The purpose of this report is to introduce the Digital Microscope, a software tool initially developed for Open University course Biology: Uniformity and Diversity and used successfully in several different Life Sciences courses. This resource aims to give distance learning undergraduates experience of the scientific processes associated with real experiments including data collection, analysis and an unknown outcome.

When developing the Digital Microscope, the aim was to provide a computer based representation of a microscope such that students can learn the use of, and limitations of, a microscope and then use it to view a range of material from the course. In the context of Biological Psychology the microscope allows students to visualize different anatomical structures at their own pace and, more specifically, use data from mounted brain sections from a number of different regions of the rat brain to determine the effects of amphetamine and cocaine on each structure. The slides provided within the software are real data from an experiment where amphetamine, cocaine or a saline vehicle were injected into rats prior to sacrifice (Rodriguez et al., 1999). The tissue was then tested for cell activation by the presence of the protein Fos, an indirect marker of the immediate early gene *c-fos*.

By using the microscope it is hoped that students will develop an understanding of experimental procedures in neuroscience, that is, what is involved in exploring some aspect of the brain at a molecular and cellular level. It also provides hands-on experience of generating data from an experiment outside of the traditional laboratory environment. More specifically, the digital microscope demonstrates how immunohistochemistry can be used to answer questions about how the brain works.

MATERIALS AND METHODS

In order to complete the experimental aspect of the course with the Digital Microscope, students are provided with a detailed Study Guide at the start of the course, although the actual data collection does not start until approximately one quarter of the way through the course, when students will have studied the basic anatomy of the brain and some of the methods used in investigating its structure and function including immunohistochemistry.

Students were provided with a CD-Rom containing the software for the Digital Microscope, additional background information and an appropriate statistical calculator. The additional background information included a brief outline of the experimental method and the synaptic actions of the two psychostimulants used. To enhance the written material provided, video clips were also given showing a simulation of the study.

Students were told that they would examine approximately three to four brain sections taken from rats that had been exposed to treatment with cocaine, amphetamine or saline. There were four possible brain regions for investigation: hippocampus, globus pallidus, nucleus accumbens and caudate putamen. Figure 1 shows a screen image of the Digital Microscope demonstrating the options available to alter the region of interest, experimental condition, subject and magnification. The software allows the student to effectively move the slide relative to the lens, akin to altering the stage position in a normal microscope. Full instructions for using the microscope were provided in the Study Guide and in a computerized tutorial lasting approximately ten minutes. In order to help students identify the Fos positive cells in the slice they were given a number of examples to use as a reference. One such example is shown in Figure 2.

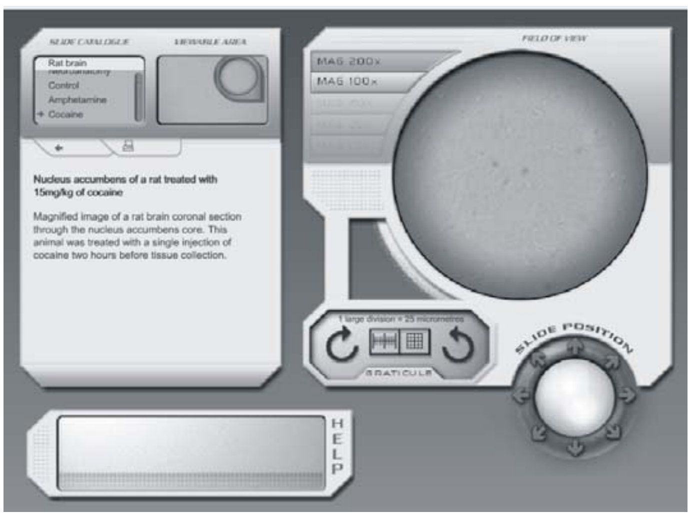

Figure 1. A screen view of the Digital Microscope. To the top left the student can select the appropriate experimental condition, from which they can select a subject and brain region. The viewable area allows the student to ensure they view the entire slice by using the arrows to control slide position. Magnification can be set to 100x or 200x, and if desired, a graticule can be added.

For evaluation purposes Fos counts were collected from 91 students and compared to the data recorded by a tutor on the course to give a percentage measure of accuracy. The counts were also used to compare the pattern of results across the three experimental conditions (cocaine, amphetamine, saline) for both student and tutor observations with the aim of testing whether any gross failings in accuracy would be likely to affect the results of any statistical analysis conducted by the students. In addition to the quantitative data both students and tutors on the course were asked to complete a brief questionnaire to aid evaluation of this tool. Student feedback was obtained prior to their marked assignment being returned so that they could not be biased by their score. Tutor feedback was obtained after they had marked approximately 20 assignments based around the Digital Microscope.

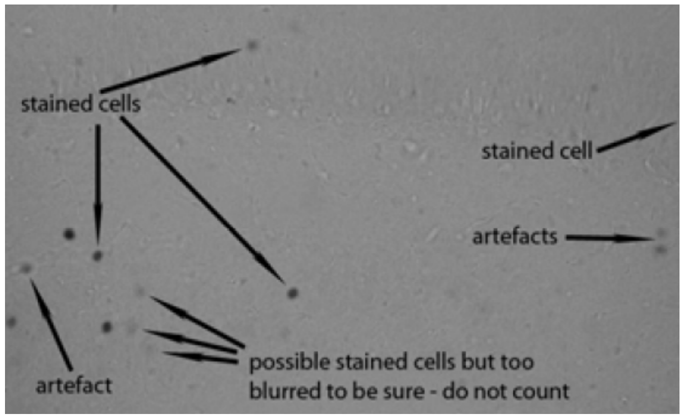

Figure 2. Reproduced with permission from the Study Guide provided to the students to assist in their collection of data from stained slices.

RESULTS

The data from 91 students testing the hypothesis that the caudate putamen responded differently to amphetamine and cocaine were compared to the data provided by a tutor on the course. On average, student scores were 240% of the tutor scores, indicating that the students may have recorded some artefacts as data points. However, while students were more generous with the counts they recorded, the overall pattern of effects remained the same. Figure 3 illustrates that both students and tutors reported finding more Fos positive cells in the amphetamine group, in comparison to cocaine and saline. Indeed, despite the very different absolute values, statistically both students and tutor reported a significant difference using a One Way ANOVA (student: $F=19.28$; $df=2, 257$; $p<0.001$; tutor: $F=31.57$; $df=2, 257$; $p<0.001$) and individual t-tests reveal both groups find highly significant differences between all three conditions.

In addition to the data comparison, both tutors and students were asked to complete similar questionnaires on the Digital Microscope. Firstly, students were asked to indicate on a 5 point scale how important they felt it was to gain experience of practical science skills during their studies. Of the 47 students who completed this element of the feedback, 73% felt that it was important or very important. A further 20% had no strong opinion (mid-scale rating) and 7% felt that it was not important. Students were then asked to rate their agreement with the statement "I found the microscope useful in providing these skills."

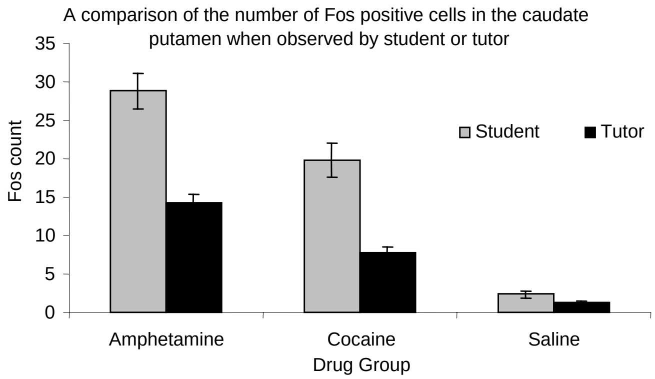

Figure 3. A comparison of student and tutor-generated data. For all drug conditions the trend of effects are maintained despite much higher recorded values by students.

Sixty-six percent of students felt that the microscope was useful in providing these skills, while 10% did not. The remaining 24% were undecided. Students then rated their agreement with statements that the Digital Microscope was useful in providing them with experience of obtaining data, recording and collating data, analyzing data and writing up experiments. Figure 4 shows that the majority of students either strongly agreed or agreed that the microscope was useful in providing experience in obtaining data and recording and collating data. By contrast, students were less convinced of its use in providing experience analyzing data or experimental write up skills.

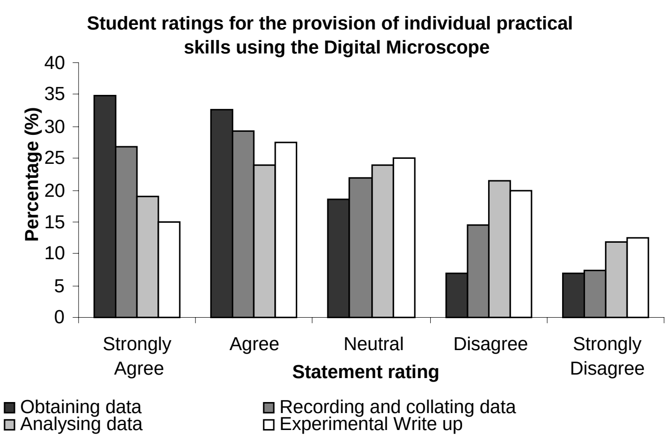

Figure 4. Students' ratings on whether individual practical skills were enhanced by using the Digital Microscope.

Tutor ratings were slightly more positive for the individual skills experience with 88% agreeing the microscope was useful for data collection and 12% disagreeing. Likewise 88% felt that it was useful for experience of data recording and collation, analyzing data and writing up experiments, with the remaining 12% in all cases being undecided, rather than negative.

An impressive 76% of students felt that the Digital Microscope had helped in their understanding of principles of practical science work, and within the remaining 24%, the majority were undecided, with only 5% disagreeing. Similarly, tutor ratings showed that 86% of tutors felt the microscope had improved student understanding of these principles and just 14% felt that it had not.

Perhaps unsurprisingly, given the inaccuracies of the counts, 86% of students felt that using the microscope had improved their understanding of the potential errors or difficulties involved in conducting experiments. Tutor ratings were almost identical to student ratings on this measure with 88% believing it had improved understanding of potential experimental problems and the remaining 12% being unsure. In line with this, only 37% of students felt that they had made accurate cell counts with 24% unsure and 39% feeling they had not made accurate counts. Tutors mirrored the students' ratings on accuracy, with 38% agreeing that students were accurate, 25% unsure and 37% disagreeing.

In order to assess actual use of the microscope, we asked students to rate their ease of use of the software: 76% found it was easy to navigate through the software, 10% were neutral and a further 14% did not find it easy to navigate through the microscope. In addition to this, 64% strongly agreed or agreed that the videos explaining tissue preparation were useful, while a further 34% had no strong opinion and only 2% disagreed, suggesting the addition of this video was useful to students' understanding of the process. Despite the majority of students finding the software approachable and the video useful, only 45% had used the microscope for studying anatomy outside of the set task.

We wanted to establish if using the Digital Microscope had improved their overall learning experience and as such we asked the students whether they had enjoyed the opportunity to contribute to a group activity, something less commonly available in distance learning. Sixty-one percent of students had enjoyed the opportunity, while a further 29% were undecided and the final 10% had not enjoyed the experience. Finally, students were asked whether using the microscope had added to the value of the course: 76% felt that it had, 14% were undecided and the remaining 10% felt that it had not. Interestingly, only 63% of tutors felt that the microscope added value to the course with the remaining 37% believing it did not.

DISCUSSION

We have demonstrated that the Digital Microscope enables students to take part in a real experiment, generate meaningful data and analyze and interpret the data, without having to be based at a University department or laboratory, making it an ideal tool for distance learning students.

Our report highlighted that while student counts were often inaccurate, relationships between different experimental conditions were preserved and the majority of students felt that using the microscope had helped develop their understanding of practical science skills. The skills students had felt were most enhanced were that of obtaining data and recording and collation of this data. Students were less convinced, although many were still positive, about the impact of the microscope on their understanding of data analysis and experimental write up. This is perhaps unsurprising given that the microscope comes with an analysis package and merely requires data entry rather than decisions to be made about which statistical test to be used. However, should this be considered important in the context of the individual course, additional statistical emphasis could be placed on the work. Additionally, students are not expected to complete a full write up for this experiment which may explain their ratings on this measure. Rather, they are expected to construct an abstract and detail independent and dependent variables and hypotheses (both null and experimental). They are then required to present the results and a brief interpretation and evaluation of the data. However, as with the statistical aspect, this could also be enhanced and the student required to complete a full write up on the study.

Of particular importance for the distance learning students, this exercise allowed students to work as a group, albeit without face to face contact. This opportunity was appreciated by the majority of students. The inclusion of the Digital Microscope in the course was reported by both students and tutors as adding value to the course.

In light of the positive feedback, we feel that the Digital Microscope adds value to the course Biological Psychology and provides students with many skills that would otherwise be difficult to achieve in distance learning. Although this report has focused on the course Biological Psychology, the Digital Microscope is used successfully on a number of other Open University courses and continues to be developed for future courses. While the microscope was initially developed for distance learning students, there is no reason that such software could not be of use in a traditional university setting. Indeed, given the legal restriction of experimentation with animals for the purpose of teaching experimental skills to undergraduate students, a tool such as the Digital Microscope may be of great benefit.

REFERENCES

Rodriguez JJ, Montaron MF, Aurousseau C, Le Moal M, Abrous DN (1999) Effects of amphetamine and cocaine treatment on *c-Fos, Jun-B*, and *Krox-24* expression in rats with intrastriatal dopaminergic grafts. Exp Neurol 159:139-152.

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