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The ZAP project: designing interactive computer tools for learning psychology

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In the ZAP project, a set of interactive computer programs called 'ZAPs' was developed. The programs were designed in such a way that first-year students experience psychological phenomena in a vivid and self-explanatory way. Students can either take the role of participant in a psychological experiment, they can experience phenomena themselves, or they can take the role of researcher and learn by discovery. ZAPs provide added value to existing learning materials about psychological topics and can elicit experiential and discovery learning activities. This article discusses the practical and theoretical considerations that underlie the design and structure of ZAPs and provides guidelines for their practical application in different educational settings.

Introduction

The first steps a student takes in the domain of psychology usually involve memorizing a large collection of basic facts. To name a few examples: 'Gestalt psychology distinguishes between a number of perceptual grouping types', 'mental rotation occurs at a speed of 60 degrees a second', and 'in classical conditioning second-order conditioning is different from blocking'. The main goal for many introductory texts is to treat as many of these facts as possible, and, with enough effort, students will probably be able to master them. However, when exploring psychology from a fact-based perspective, it is easy to lose sight of the not too obvious relations that sometimes exist between individual phenomena. A standard course in introductory psychology should involve much more than rote learning. Students need to learn that psychology is an empirical science, and that psychology's base of established facts is the product of a long history of performing experiments and developing theories. Learning to think critically about psychological topics begins with asking questions such as: what do the facts *mean*, how have they been derived from empirical studies, and in what way are psychological phenomena reflected in daily life? Modern developments that have spawned technological innovations, such as the Internet, can aid in the creation of content that fosters these types of complementary learning activity. For example, Newcomb *et al.* (1998) gave an overview of the possibilities and benefits of embracing

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new technologies such as the World Wide Web. They regarded new technologies in classroom settings as promising because these motivated students highly and allowed for new educational applications. The number of web-based resources on psychology has increased in recent years because publishers have started to provide online supplementary material to new editions of introductory textbooks. Most, if not all, introductory psychology textbooks are now accompanied by a (temporary) subscription to an accompanying website or set of websites. A distinction can be made between material that does not ask for much active participation on the student's part (e.g. supplementary texts, figures, video, or lists of hyperlinks to related online material) and material that can only be fully processed through 'active' participation (such as quizzes or programs that require some kind of response from students).

The interactive, educational material in psychology has a number of important limitations, even when it supplements textual (book) content with interactive multimedia material. We focus on two aspects by which material can be evaluated: its *scope* in dealing with the wide range of topics that are part of psychology and its *consistency* in the interaction with students, through the user interface and through the style of information presentation.

Scope issues

With respect to its scope, psychology and its sub-disciplines cover a wide range of phenomena that are to some extent related to the (mental) behaviour of organisms. The wide range of topics that is covered by all major introductory textbooks on psychology reflects this large scope—see, for example, Gleitman *et al.* (2004) and Gray (2002). It is therefore expected that the breadth of psychology will be reflected in material that aims at supplementing these types of textbook. Instead, interactive packages focus almost exclusively on topics in the field of cognitive psychology. An example of such a package is the Wadsworth Cognitive Psychology Online Laboratory (called 'CogLab'; its corresponding website can be found at http://coglab.wadsworth.com/). Its developers claim that CogLab 'uses the power of the Web to teach concepts using important classic and current experiments that demonstrate how the mind works'. The overview of topics covered by CogLab experiments shows that almost all these experiments cover topics from cognitive psychology. Another example is the Introduction to Cognitive Science website—this is described in Goolkasian and Van Wallendael (2001); its corresponding website can be found at http://cogsci.uncc.edu/. A reason for the one-sided interest in psychological topics could be that experiments in cognitive psychology are usually simple to set up. The result is that current material is limited because it does not cover a wide range of psychological phenomena.

Consistency issues

Although in the case of (simulated) experiments a similar procedure is followed every time, there is still little overall consistency in the user interface and in the level of interactivity that is used. First, inconsistencies in the user interface may be caused by the fact that some of the available material has been in development over a number of years, causing internal inconsistencies; an example is the popular Psyk.trek™ package, which has been in development for a number of years. Second, there are inconsistencies in the level of interactivity that is used. Interactivity varies from a demand for active participation on the part of students (e.g. participating in an experiment) to watching a visual slideshow of relevant material on some topic. A large part of available material has a high *expository level*, which means that phenomena are explained by a discussion of a psychological theory, after which a student can attempt to confirm or verify the theory by finding an appropriate result during some kind of activity. This approach reduces active participation by students because they merely need to confirm ideas that already have been explained to them. From an instructional point of view, use of a high expository level may not be the most effective method of presenting information to students. More modern and more interactive methods focus on students' active experience, exploration, and discovery of information. These methods took up a central position in the ZAP project.

The ZAP project

The ZAP project focused on the development of interactive material on psychological topics, avoiding the limitations that have been set out above. ZAP stands for 'Zeer Actieve Psychologie', which can be translated as 'very interactive psychology'. In the context of the project, a collection of interactive modules called ZAPs was developed. The purpose was to engage students in an immediate experience with psychological phenomena. In order to foster immediacy, ZAPs are short: they typically take 10–15 minutes to complete. The general goal of the project was to design modules that would deal with topics in psychology, focusing on active participation while increasing engagement in learning by confronting students with their own experience of a phenomenon. The concept of active participation as a core process during learning is closely related to the theory of 'experiential learning', which views knowledge acquisition as a process of knowledge *construction* (Kolb, 1984). The best way to construct knowledge is to learn from concrete experiences and reflect on these. The theory posits that experiencing and reflecting are both prerequisites for achieving abstract conceptualization. A concrete experience requires an active disposition. Learners need to perform actions in a situation and observe the effect of these actions. Reflection means understanding the results of the actions that are performed in a particular situation, so that predictions can be made regarding the outcome of similar actions in similar situations. Finally, abstract conceptualization means gaining understanding of a more general principle, so that predictions can be made about the effect of other actions in other situations. Clements (1995) found evidence for the effectiveness of experiential learning of psychology. Students reacted more positively and with greater interest to a course on developmental psychology when the material was made experiential (through the use of real-world applications) than when they were taught primarily by lectures. Seng Tan (2004) argues that implementing innovations that shift a passive learning perspective to that of active problem-solving can be problematic. Careful design of instruction should foster this process, especially when it is adapted to students' experiences in problem solving. In the ZAP project, elements of experiential learning were implemented by focusing on active experience and reflection on results. Students experiment with psychological phenomena by recreating or simulating them in a 'virtual laboratory'. Working in such a laboratory requires students to devise hypotheses and to test their validity by performing relevant experiments. On a computer, virtual laboratories are usually recreated through simulation of the original situation. An underlying assumption is that working within a virtual environment is (relatively) similar to experiencing phenomena in real-world situations. Evidence for this assumption was found in an early study by Benedict and

Butts (1981), who compared two situations, one in which students designed and performed a 'real' experiment and one in which students worked with a simulation to design and run experiments. They showed that learning effectiveness after working with computer-simulated experiments was equivalent to designing and running a real experiment. Moreover, students reacted favourably toward the computer simulation, claiming it improved their understanding of applying statistics to their experimental data.

The remainder of this paper presents the principles and their application that guided the structure and design of ZAPs. First, we describe the main design principles. This is followed by a description of the way researchers have implemented these principles. We describe three example ZAPs in more detail to illustrate the theory-to-practice approach that was followed. We conclude with a description of the different methods that can be used to utilize ZAPs in psychology classes.

Design principles

The aim of the ZAP project was to design and develop a set of interactive learning modules on different psychological topics, putting into practice the theoretical ideas that have been set out in the introduction. The design of the generic structure and content of ZAPs was guided by a set of minimum requirements, or *design principles*. Six design principles were derived from theoretical and practical considerations.

The first two design principles were derived from the theory of experiential learning. First, it is essential that each ZAP contains at least one part with a concrete experience of a psychological phenomenon. This 'activity' part should be the central element of a ZAP. Second, students should experience or discover a psychological phenomenon for themselves, before being told the theory behind or technical background to the phenomenon. Four additional design principles were derived from a requirements analysis of both existing learning material and interviews with psychology teachers and students. The third design principle states that the set of ZAPs should cover a wide range of topics in psychology, not just the topics in cognitive psychology. Fourth, the learning material and the activities elicited from students should be consistent. The implication is that, although the range of topics should be diverse, they should be organized into a relatively small collection of different types of activity. The fifth design principle was felt to be especially important for students: textual material should be short, engaging, and avoid complex explanations whenever possible. Finally, in order to deploy ZAPs in a variety of educational settings, the technical demands for 'running' them should be kept low.

From principle to practice

The design principles that were formulated in the previous section together formed the basis for the ZAPs, before and during the development process. This section explains the way the abstract design principles were implemented.

Design principle I: central activity

This design principle influenced the underlying structure that forms the basis of all the ZAPs. It was decided to make the interactive part (the 'activity component') a central component within a ZAP. This means that the purpose of the other components is to introduce or explain the phenomenon that a student works with in the activity component.

Design principle II: emphasis on discovery

Since this principle states that explanations of a phenomenon should be avoided until after a student has had a concrete experience of it, ZAPs start with a short introduction, followed by the interactive component. Only after that, the theoretical explanation for the phenomenon that students have just worked with is discussed.

Design principle III: wide range of topics

In order to cover a wide range of topics in psychology, an overview of psychological domains and relevant topics was constructed. A number of leading introductory psychology texts were examined, and a list of 12 distinctive areas that are discussed in most or all textbooks was created. They were: neuroscience, sensation and perception, learning, attention, memory, thinking, language, labour and organization, personality, clinical psychology, developmental psychology, and social psychology. For each of the areas a list was made of psychological experiments and phenomena, the learning of which could be supported by ZAPs. The list was improved by teachers of introductory courses in psychology at a number of Dutch universities. For each area this led to a list of approximately 10 psychological phenomena that were considered the most suitable to be supported by a ZAP.

Design principle IV: consistency in activities

Although a variety of topics in psychology were covered, the type of activities supported by ZAPs should be as similar as possible. To achieve a generic structure, three general types of activity were distinguished. Independent from the phenomenon it covers, a ZAP should always conform to one of the three types. The division into a small number of types was achieved by generalizing over the different functions that ZAP activities can have. Differences between the functions are mostly limited to the central component, the activity. The functions of the activity were defined as *experiences*, *discoveries*, and *experiments*. To clarify the differences between the ZAP types, a schematic overview of the structure of each of the types is shown in Figure 1.

All ZAPs are built of the same components. Differences between the ZAP types lie solely in their interactive component. The introduction, instruction, theory, and further information parts are all textual components. The interactive components are based on the function of the activity. They can be an experience, discovery, or experiment. In *experience* ZAPs, the purpose of the activity component is to have students directly experience a psychological phenomenon for themselves. This experience is especially useful in cases where having a first-person experience of it will lead to more understanding than reading a description of the phenomenon. The experience does not involve working through experimental trials, which means that the experience does not result in data (as is the case with experiment ZAPs). Examples of phenomena that can be experienced are visual illusions, but also higher mental processes such as biases in reasoning or problem-solving methods. In *discovery* ZAPs, learners take the role of experimenter in a virtual

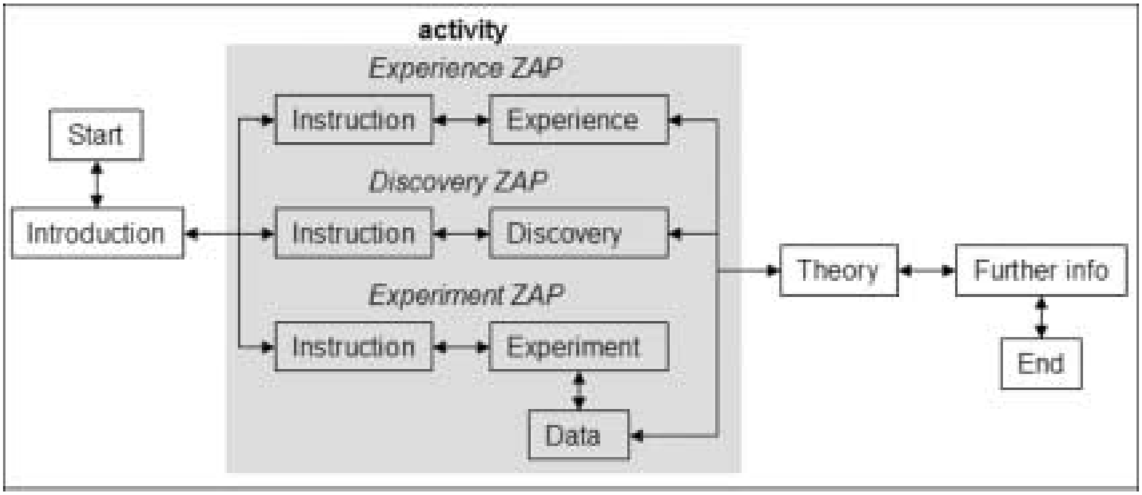

Figure 1. Schematic structure of the three main ZAP types

laboratory. By setting up and performing experiments, a model of the behaviour of a virtual participant can be derived. The implication is that discovery ZAPs are especially useful when a psychological phenomenon can be explained by a model. Example phenomena from psychology that can be modelled in a discovery task are pain sensation—for example, the gate-control theory of pain (Melzack & Wall, 1965)—and classical conditioning. In *experiment* ZAPs, students take part in a (classical) psychological experiment as if they were themselves participants in a real-life activity. An experiment consists of several trials in which the participant's task is to respond in various ways to stimuli. The end result is a data set that shows the way a theory of cognitive processing can explain results obtained from an experiment. This type of ZAP is appropriate in cases where experiencing what it is like to participate in a psychological experiment helps students to understand the theory that is derived from its results. Because the goal was not to provide an exact simulation of the original experiment, but to simulate the experience of participating in it, not every psychological experiment was considered suitable for this use: only experiments that show relatively clear results after a small number of trials were made into a ZAP. Example experiments that show this type of result are the mental rotation experiments by Shepard and Metzler (1971), that illustrate the relation between perception and mental imagery, and the Stroop effect (Stroop, 1935), which illustrates the interference between controlled and automated tasks.

Design principle V: avoid complicated textual material

In order to meet the requirement of avoiding long, complex explanations, textual components were kept short by focusing on the phenomenon covered by the ZAP, and by using the same general format in all ZAPs. The guideline while writing the textual material was that all texts should be easy to understand for first-year psychology students. For example, the introductory component of a ZAP always consists of a concrete example from real life related to the phenomenon. Students can relate to a concrete example because they recognize it from their own experience. This introduction is used as a stepping-stone for the activity. The theory component focuses on explaining the phenomenon that can be observed in the activity and avoids unnecessary side issues. Use of complex terms was avoided. If necessary, extra information on special terms (e.g. definitions) or about persons (e.g. a famous researcher in psychology) could be accessed from the text in a glossary. For those actions that could be performed in all ZAPs (e.g. navigating through components or printing information) simple icons were used. The effectiveness and ease of use of these measures was evaluated by carrying out a different usability study early on in the project. In both collective and individual sessions, first-year psychology students commented on the usability of different components of a number of ZAPs. They also offered comments on the layout and content of each ZAP. The evaluation served as a base for revision of all textual components.

Design principle VI: low technical demands

As a means of avoiding high technical demands, the need for any special software to be installed to 'run' ZAPs correctly was avoided. ZAPs were partly written in Macromedia Flash, and were made accessible from within a standard web browser. Therefore, the Macromedia Flash plug-in is requireed to run the ZAPs, but this is a standard application on most computer setups. A ZAP is a completely self-contained module, which means that no external links (to resources on the World Wide Web, for example) are used.

All ZAPs were developed using the practical implications of the design principles as described above. Currently, 57 ZAPs have been developed, divided over 12 domains. An overview of the ZAPs that have been developed so far is given in Table 1.

In a number of ZAPs, multiple activities are used (e.g. an experience and an experiment). Within Table 1 these are displayed on separate rows.

Examples of different types of ZAP

To really understand the style, conciseness, and interactive level of ZAPs, one has to work with and experience one or more of them. As a means of indicating their content, an example for each of the three ZAP types will be given. These ZAPs are representative of the complete collection.

Experience/experiment ZAP: Ponzo illusion

The Ponzo illusion concerns a perceptual phenomenon that can be explained by the fact that our perception of the size of objects is relatively constant despite the fact that the size of objects on the retina varies with distance. The ZAP's goal is to confront students with an experience of the illusion, which is created by showing two horizontal lines on a background of oblique lines. The activity component of the ZAP is split into two, an experience part and an experiment part. In the first part, students explore different properties of the setup that influences perception of the illusion. An example screen is shown in Figure 2.

The figure shows a typical situation in the experience part. Students are set the task of making both horizontal lines equivalent, by varying the length of the bottom horizontal line. When they think both lines are equal, they can check the answer and are given feedback on the difference in lengths. They can vary the properties of the illusion by modifying the number of oblique lines.

Table 1. Overview of ZAP developed during the project, divided over domain

Domain	Topic	ZAP type
Attention	Selective attention	Experience
	Simon effect, Spatial cueing, Stroop effect, Attentional blink, Partial report	Experiment
Neuroscience	Gate-control theory of pain, Split-brain	Discovery
	Synaptic transmission	Experience
	Genetics	Discovery + Experience
Memory	Brown-Peterson task, Recalling information, Memory bias, False memory task, Memory span, Operation span, Serial position task, Sternberg search, Encoding specificity	Experiment
Thinking	Wason 2-4-6 task, Wason selection task, Syllogisms, Missionaries and cannibals, Gestalt problem solving, Decision making	Experience
	Mental rotation task 2-D, Mental rotation task 3-D, Mental scanning, Sentence verification	Experiment
Learning	Classical conditioning	Discovery
	Naive physics, Implicit learning, Fan effect	Experiment
	Concept formation	Experience
Development	Balance scale task, Moral development, Conservation tasks	Experience
Labour	Personnel selection procedure	Experiment
Personality	Big Five personality inventory, Recognizing emotion	Experiment
Perception	Ames room illusion	Experience
	Ponzo illusion	Experience + Experiment
	Signal detection I (line-up), Visual search	Experiment
	Signal detection II (graph), Lateral inhibition	Discovery
Social	Cognitive dissonance	Experience
	Stereotypes	Experiment
	Prisoner's dilemma	Experience + Discovery
Language	Lexical decision, Word superiority, Word frequency effect	Experiment
	Feature nets	Discovery
Clinical	Obsessive-Compulsive Disorder	Experience
	Emotion Stroop task	Experiment
	Multiple personality disorder, Mood disorder	Discovery

In the experiment part, students are shown different situations in which the illusion occurs, and their task is to make both lines equivalent, after which they proceed to the next experiment trial. At the end they are presented with their results so that they can observe the extent to which the illusion occurs for them.

Discovery ZAP: split-brain

A small proportion of the population suffers from a severe type of epilepsy. In a few cases, a beneficial treatment is to cut the corpus callosum of these people, that is, the thick band of neural fibres that joins the two brain hemispheres. The effects of this radical surgical procedure are surprisingly small: these 'split-brain patients' are well able to get on with their normal lives. Using clever laboratory techniques, neuroscientist Roger Sperry showed that there are interesting

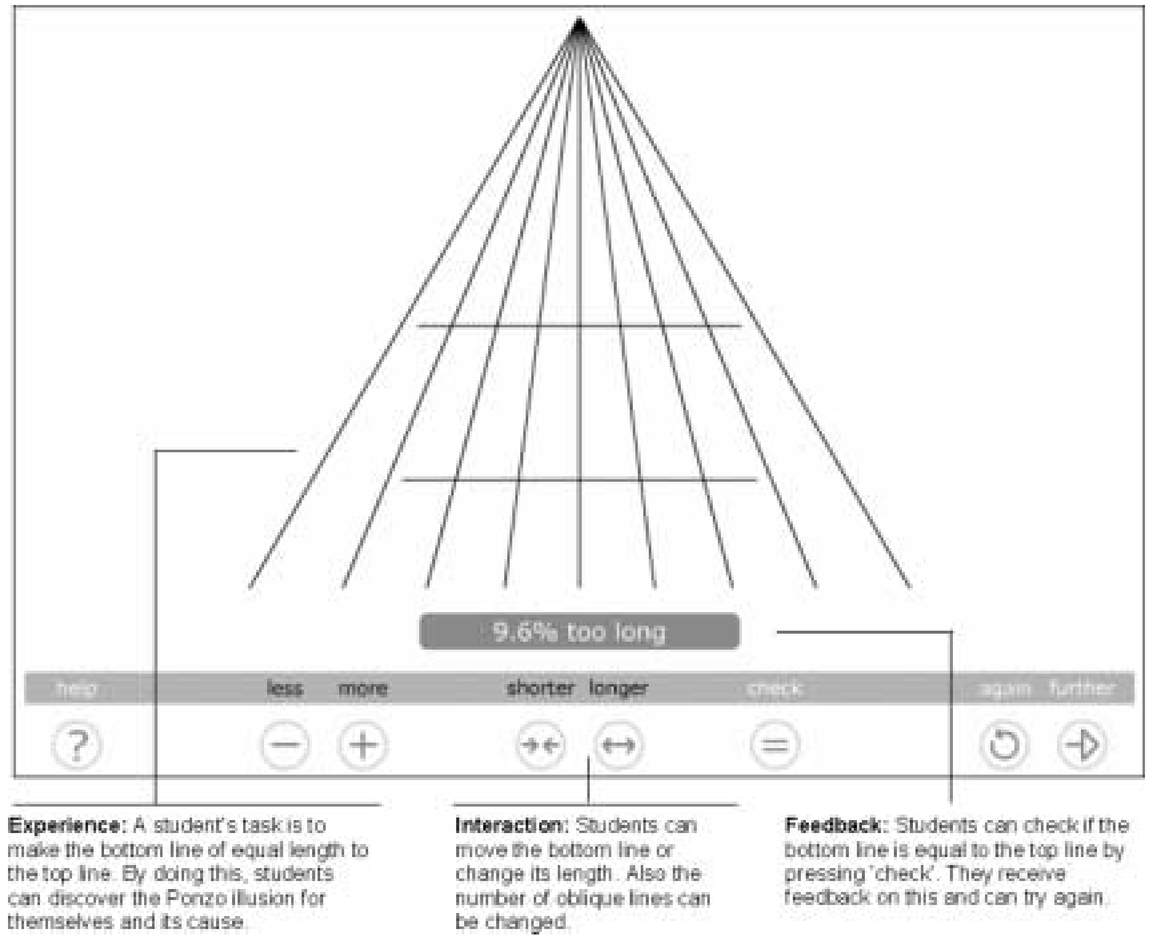

Figure 2. Example screen from a combined experience/experiment ZAP: Ponzo illusion

phenomena to observe from experiments with these split-brain patients. His experiments involved a task in which a patient is seated in front of a screen on which words or pictures are presented for a very short time. The split-brain ZAP allows students to 'replay' some of these experiments in a virtual laboratory. An example screen of the activity part of the split-brain ZAP is shown in Figure 3. Explanations for the different elements in the activity part have been added to the figure.

Some elements that can be seen in the figure are part of all ZAPs (that is, also in experience and experiment ZAPs). There is a menu on the left, a 'print version' option on the top right (which prints all the text parts and (if relevant) data from an experiment), and a navigation option on the bottom right. Other elements are specific to discovery ZAPs. Students can choose different settings, after which they start an experiment (in this case, with a virtual patient as subject). The effect of the chosen settings is shown to the student in different ways. In this case, the course of the experiment itself is shown together with information travelling through neural pathways within the split-brain patient. A trial in the task finishes with the patient's verbal reaction. To help students get an overview of the experiments that they have performed so far, a

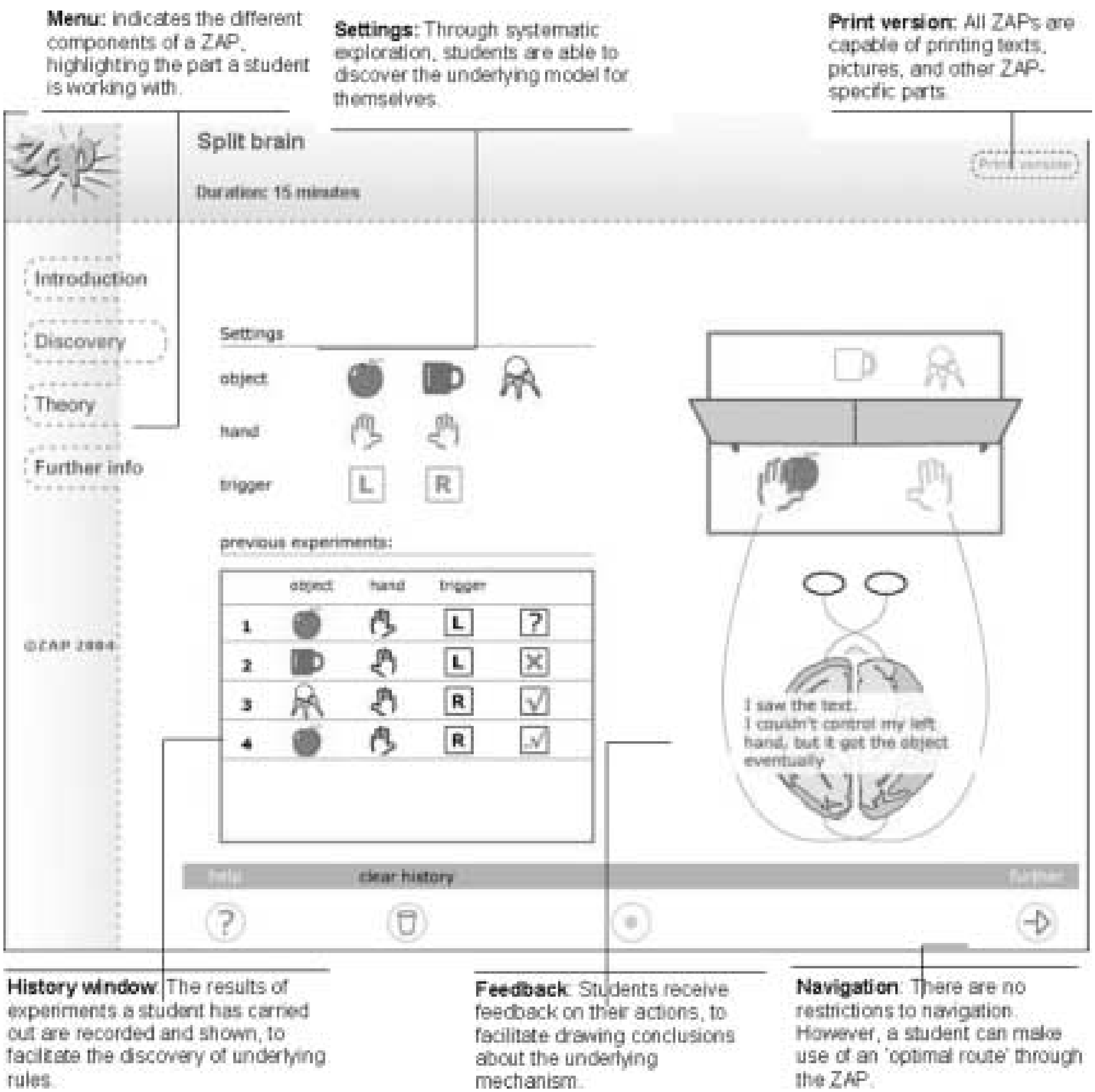

Figure 3. Example screen from the activity in a discovery ZAP: split-brain

history window collects and displays all their trials. It shows the settings that a student has chosen together with the outcome of that particular trial. By performing a series of trials, students can infer the model that underlies the simulation.

Experiment ZAP: mental rotation

Rotation experiments, originally performed by Shepard and Metzler (1971), have proven to be a suitable entry point for a discussion on the topic of mental representation. In such an experiment, participants are shown pairs of objects (the 'stimuli') that are rotated with respect to each other. A participant's task is to judge whether the objects are each other's mirror images. The original experiments consisted of more than 1000 experimental trials, but some interesting effects can already be observed after a smaller number of trials. Stimuli used in a mental rotation experiment can vary. Two ZAPs were created, one that uses two-dimensional (2-D) stimuli and another that uses three-dimensional (3-D) stimuli. Figure 4 shows an example of the stimuli used in the 3-D ZAP.

Experiment ZAPs make use of a specified number of trials (preceded by a few practice trials). Most experiments use fewer trials than used in the original experiment. Limiting the number of experimental trials was done on purpose, because the phenomenon described in a ZAP can usually be shown after a smaller number of experimental trials than used in the original experiment. After completing the experiment, the results are shown in the data component. An example of the data component for the mental rotation 3-D ZAP is shown in Figure 5.

Students can view the data from their experiment in three different formats. The figure shows the results in a diagram, other options are to view data in tabular format, or to view 'raw data' (that is, the settings and results on a trial-by-trial basis). The latter option allows students to copy their data to another application for further analysis (e.g. SPSS). At an early stage it was observed that students found it useful if they were able to check if their own results are 'normal', that is, comparable to the average results of other students. For this reason, reference data were added to the data component. Figure 5 shows reference data, and it can be observed that the student in this case has a faster average response time than shown in the reference data. Reference data show typical experimental results, which conform to the results predicted by theory. The reference data are built into the ZAP, which means that they provide a static comparison measure. A more dynamic measure is provided by the ZAP monitoring tool, described in the next section.

Application of ZAPs in psychology education

ZAPs can be utilized in different educational settings. Here we will discuss two practical applications: individual use and class data collection. First, students can work individually with the

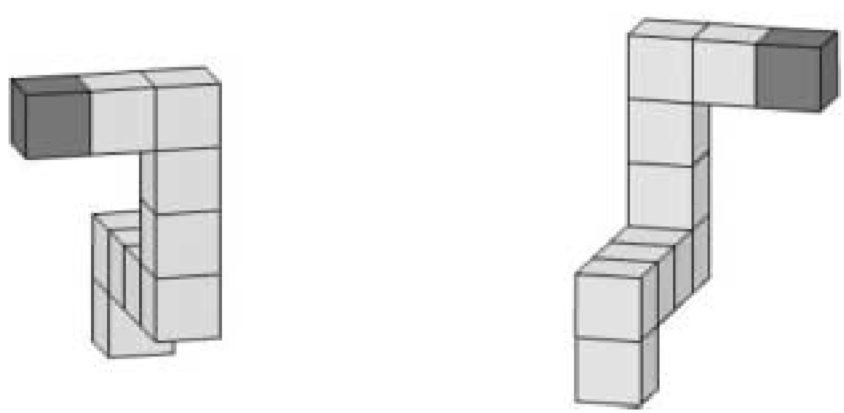

Figure 4. Example stimuli from an experiment ZAP: mental rotation 3-D

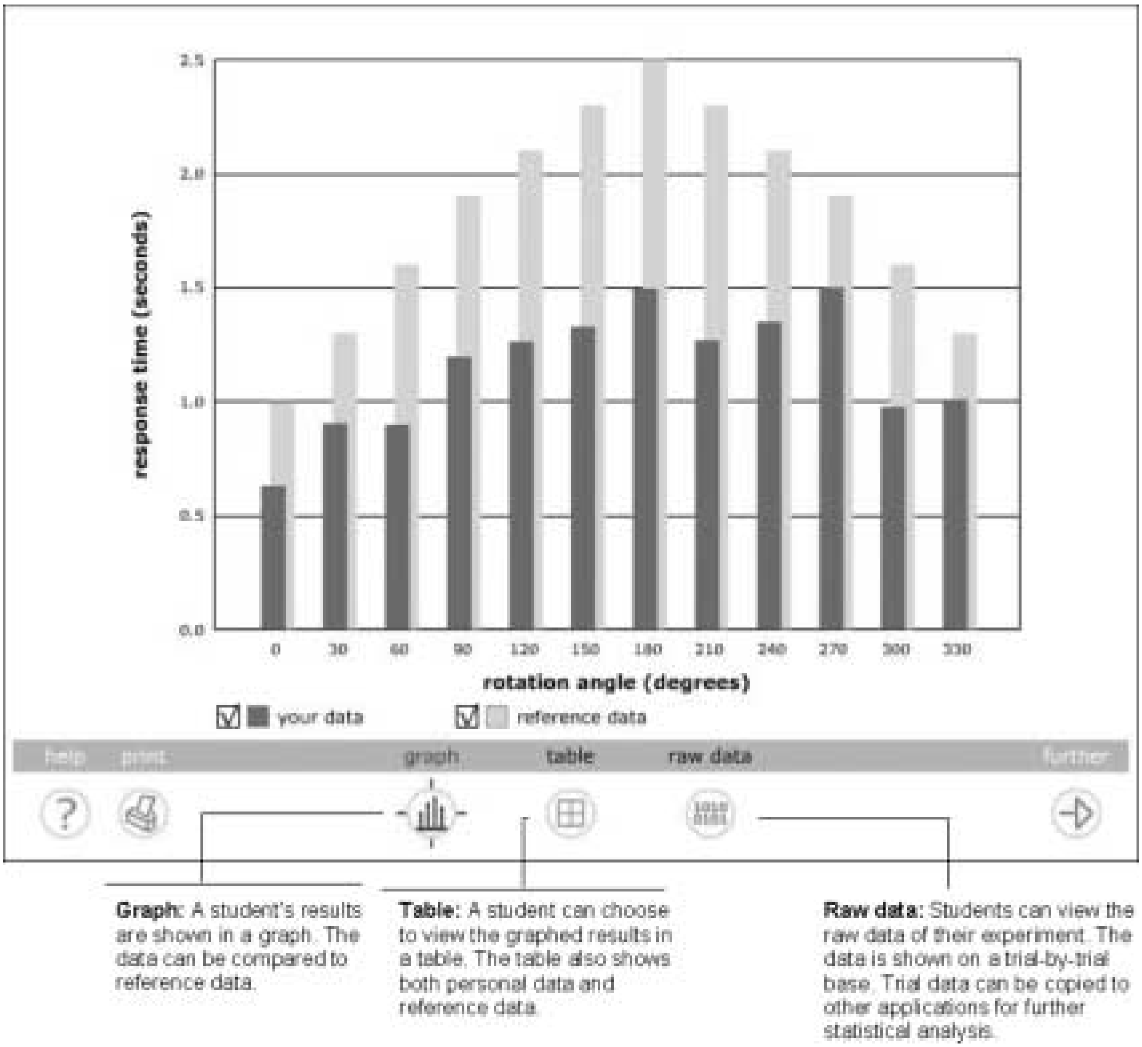

Figure 5. Data component of the mental rotation 3-D ZAP

ZAPs. Individual sessions can be arranged in a practical classroom setting where students work with an assigned set of ZAPs, but the design also allows for students to work with ZAPs at home. Second, ZAPs can be used in a collective setting, for example during a lecture. To help increase active participation by students during lectures, in the project an additional tool called the 'ZAP monitor' was developed. The ZAP monitor combines individual use of ZAPs with a classroom demonstration of them. The ZAP monitor works as a class data collection module. It collects, aggregates, and displays the data that result from an experiment that is performed by a number of students simultaneously. An example of the monitor tool is displayed in Figure 6. This figure shows data from a session in which a group of students performed simultaneously in a mental rotation experiment. As the window in the upper right of the figure shows, the graph represents data from 20 people: 19 students have already

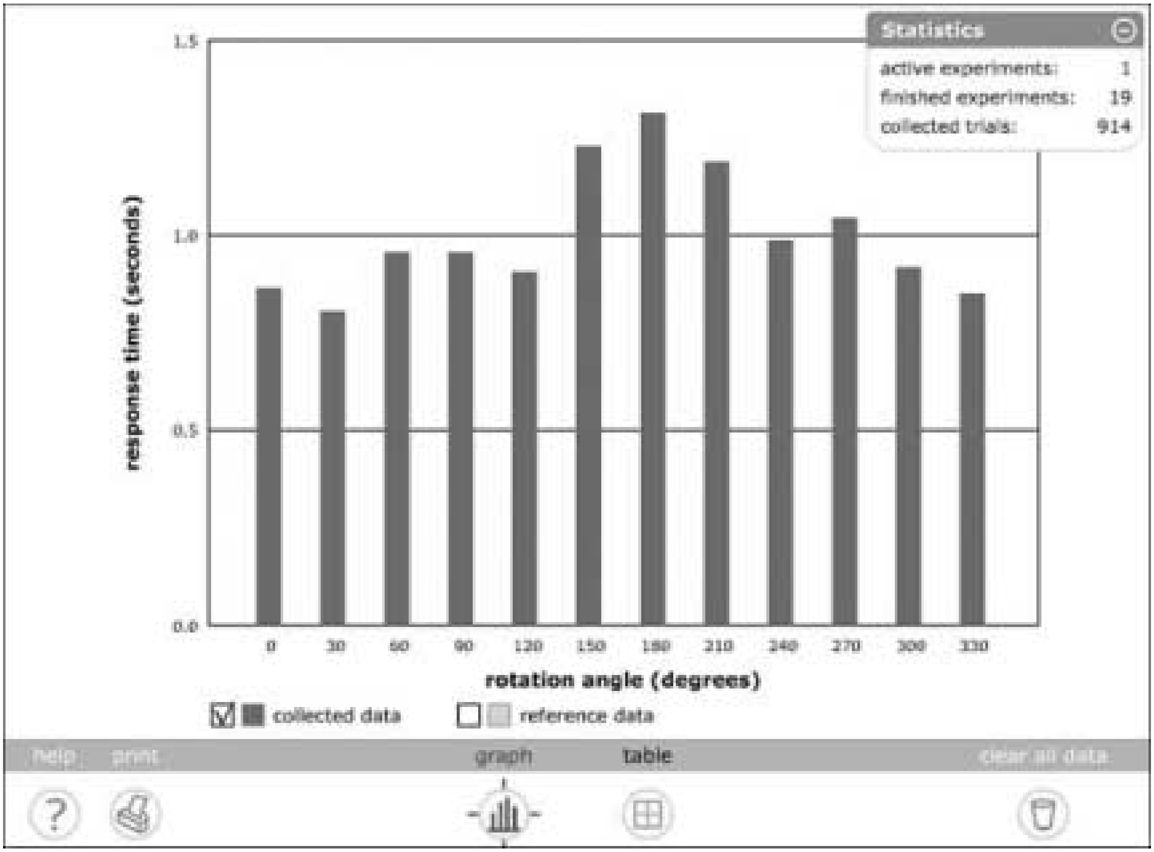

Figure 6. Monitoring facility in function

completed the experiment and from one student data was still being collected at the time the snapshot was taken.

Before working with a ZAP, students individually log on to the monitor, so that their experimental data are subsequently sent to it. The central monitor computes relevant averages from the data it receives and displays them in a graph or table. The displayed data is updated in real-time, which means that the shape of the displayed graph changes continuously while different students participate in an experiment. Because the aggregated data usually shows a deviation from data that is collected individually, the monitor facility has an important educational advantage. It lets students experience in what way individual data from an experiment can deviate from predictions that are derived from a theory. In this way, students are made aware of the necessity in psychological experiments for having a group of subjects work in the same experiment, and that it is not unusual for data from one person to show deviations from the theory.

Conclusion

The reaction to ZAPs has been very positive, by psychology teachers as well as by students. ZAPs are now in use at most universities in the Netherlands. The Dutch versions of the ZAPs are freely available from the project's website at http://zap.psy.utwente.nl. The complete collection has been translated, and English versions of the ZAPs are distributed by the American publisher W. W. Norton. An empirical evaluation of the effectiveness of ZAPs—reported in Hulshof *et al.* (2005)—explored the added value of the activity component of ZAPs. In the experiment, students worked with different ZAPs (of all three types) under controlled circumstances. One group, who worked with complete ZAPs, was compared to a control group who worked with the same ZAP, but without the activity component. Results showed that the control group initially outperformed the experimental group. However, on a retention test the differences between the groups disappeared. These results indicate relatively good long-term learning effects from working with ZAPs.

On a more general note, in the ZAP project the creation of tools for supplementing teaching of (introductory) psychology was guided by an interesting and fruitful approach. The approach combined thoughtful deliberation on the design principles that form the backbone of each finished ZAP with a rapid prototyping strategy that led to fast reconsideration of early design decisions. The use of this combination of strategies facilitated conforming and adapting to the requirements that were stated by the intended user base (teachers as well as students), while maintaining control over theoretical demands. A goal for future research could be to find, evaluate, and optimize novel learning situations that grow out of the use of ZAPs in different educational settings. Examples of possible learning situations are to adapt the structure of ZAPs to the individual learning style of a student or to support collaborative learning settings for those ZAPs for which they are found to be especially appropriate.

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