Abstract

Due to rich historical legacy as well as recent advances in the field, cognitive psychology spans a large array of research methods, experimental paradigms and measuring techniques that provide a powerful set of tools in the study of cognitive functions. A sample of research methods from two core approaches, experimental psychology and cognitive neuropsychology, are presented along with some of the examples and considerations of their use.

Introduction

Through the history of psychology, many research methods have been developed. The rise of cognitive paradigm has also brought about a development of many new and exciting research methods, experimental paradigms and measuring techniques. Today we can observe four general approaches to research in cognitive psychology.

One way of studying cognitive processes is by making use of introspection. Even though dependent on conscious experience, introspection can provide us with valuable insights into studied phenomena. Many researches (Nisbett and Wilson, 1977; Seger, 1994; cit. in Eysenck, 1995) argue that an individual’s introspections about what is determining his or her behaviour are often inaccurate and limited in scope due to lack of conscious awareness of many cognitive processes or their products. But even though sometimes despised as subjective and unscientific, introspection has again found its validity and place in psychology, especially when properly used and interpreted. Rather than told to interpret their experience participants are nowadays asked to describe the contents of focal attention. Their reports are not used as a direct description of cognitive processes, but rather treated as any other behavioral data1.

Cognitive processes and structures can also be explored indirectly by observing the behaviour to which they lead, like measures of speed and accuracy of performance. This approach has proved to be useful in the development and subsequent testing of the majority of theories in cognitive psychology. The problem with use of such data is that they provide only indirect information about internal processes. Behavioural data are also usually gathered in the laboratory setting, which can often differ substantially from real-life situations. Despite their drawbacks, classical experimental methods still present the core approach to testing and developing models of cognitive functions. Ingenious experimental designs have provided many breakthroughs in understanding human cognition.

With fast development of computers and computing techniques, computational modeling today presents a very useful approach in the study of cognitive functions. Building running models of cognitive functions not only forces psychologists to specify in detail every assumption and detail of a theory, but also provide a powerful means for their testing and development.

Another very popular way of studying cognitive processes, also brought about by recent development in technology, is the more direct approach of measuring actual brain functioning during performance of a cognitive tasks. New technical advances enable researchers to measure activity in different parts of the brain with high spatial and temporal resolution.

As functional brain imaging techniques and computational modeling are presented in detail elsewhere in this volume, our presentation of methods and studies of cognitive function will mostly focus on two core psychological approaches: experimental cognitive psychology and cognitive neuropsychology.

Experimental cognitive psychology

Theoretical models in cognitive psychology characterize mind as a complex information-processing system. The aim of research in cognitive psychology is to specify the functional processes and representations that underlie performance on cognitive tasks. Information-processing framework assumes specific properties of the cognitive system, like limited capacity and sequential operation, which enable its to put forward specific hypotheses about responses, their reaction times and accuracy that can be tested in experimental settings.

Chronometric methods

Reaction times (RT) provide an intuitively appealing indirect measure of brain function and efficiency. The time-honored procedure of RT has many variations – simple, choice, disjunctive, and associative, with regular or irregular foreperiod warning signals. For example, the “subtraction method” enables us to assess the amount of time needed to complete a cognitive operation by computing the RT-difference between two tasks that differ only in the addition of the cognitive operation we are interested in.

The most straightforward application of the subtraction method involves comparison of two uncomplicated tasks, the simple reaction time (SRT) task and the choice reaction time (CRT) task. In the SRT, subjects make a simple motor response to a specified stimulus. The RT measures how long it takes the subject to perceive the stimulus and execute the motor response. Choice RT tasks involve some additional degree of cognitive processing and/or decision making as they demand a choice among at least two possible responses.

In RT experiments timing parameters such as stimulus presentation duration and interstimulus interval frequently serve as additional independent variables. Besides RT, response accu-

1 One of important introductions of introspection as a valid scientific method can be found in Dennett’s book “Consciousness Explained” (1991).
racy can also be used as a dependent variable in a range of different stimulus presentation paradigms with a number of task performance criteria. Combined with RT, it provides a measure of accuracy-speed tradeoffs, such as the changes in accuracy when time to perform is changed. Finally, verbal reports by subjects of their own conscious processes during task performance have also been used as dependent measures in RT experiments.

**Sternberg’s paradigm**

The basic paradigm for studying speed of retrieval from short-term memory was introduced into psychology by Sternberg (Eysenck, 1969). Sternberg built on the assumption that reaction time from stimulus to response is really a composite or a sum of reaction times of a series of sequential subprocesses that one has to carry out in order to complete the task. He suggested that in order to study a specific component, one has to set up an experimental task in which all other components are kept constant and only the component that we are interested in is systematically varied. In his experiment, two to six items, generally referred to as the “memory set”, were presented to the subject in short succession. A probe item was then presented shortly after the memory set. The subject’s task was to decide as rapidly as possible whether or not the probe matched one of the items in the memory set. The results showed that the reaction times increase linearly with number of items held in memory, which suggests that short-term memory scanning is a serial process.

**Tachistoscopic methods**

Tachistoscopic methods have proven to be extremely useful tools for addressing interesting questions in psychology and neuropsychology. Much of the early tachistoscopic research in psychology was concerned with how much information a person could apprehend from a single brief fixation and with the determinants of visual “attention” (Hamay, 1986). The intensive application of tachistoscopic techniques to neuropsychological questions, especially to question of hemispheric asymmetries of function, is more recent, dating essentially from the 1960s. Standardized and normed tachistoscopic tasks which provide information regarding the nature and quality of hemispheric specializations, visual memory functions, simple visual sensory acuity and visual-motor response speed can be most useful in individual patient assessments.

**Dichotic listening research**

The dichotic listening task involves presenting subjects with two different auditory stimuli simultaneously, one to each ear. Kimura (1961, cit. in Hannay, 1986) employed this procedure, using spoken digits as stimuli, with subjects known to have damage to either the left or the right temporal lobe. Each trial consisted of three pairs of dichotic digits presented in rapid succession. Immediately afterwards, subjects were asked to recall as many of the six digits as possible, in any order. The main observation was that even in neurologically normal subjects right ear advantage (REA) occurred. The participants typically reported items presented to the right ear with greater accuracy. On the basis of evidence from animal studies Kimura explained that the ear asymmetry is based on stronger contralateral than ipsilateral projections from each ear.

**Vigilance tasks**

In vigilance tasks, participants are typically presented with a specific task that has to be carried out over a longer period of time, aimed at assessing the participants’ ability to sustain their level of performance. Several different types of vigilance tasks exist that differ in operations specified by stimulus presentation paradigms and instructions to the subject.

In monitoring, the subject is exposed to continuous stimuli but responds only to occasional signal or target items. Designed to keep memory, motor, learning and problem-solving requirements to a minimum, while requiring continuous sustained attention or “vigilance”, monitoring tasks are used to assess and augment the subjects’ ability to maintain peak levels of alertness and attention while performing monotonous tasks. Supervisors in a production line or airspace controller often face such situations.

Continuous performance task (CPT) is a relatively brief measure of vigilance. It was originally developed by Rosvold and his associates (Hannay, 1986) and it is the most widely used measure of sustained attention. CPT is a class of rapidly paced, relatively brief vigilance tasks with discrete target and nontarget perceptual stimuli, the exact nature and timing of which vary substantially from one application to another. The CPT paradigm has been much studied in cognitive electrophysiology where it is known as the oddball paradigm (Reinvang, 1998).

**Distractor techniques**

Distractibility is assessed by the extent to which performance deteriorates in the presence of task-irrelevant stimuli. Data from the distraction paradigm provide evidence that familiar stimuli are easier to ignore than novel and unexpected ones (Pashler, 1998). One of the questions that a distractor technique can help address is the rate at which information held in short-term memory decays during distraction. The Peterson and Peterson technique (1959, cit. in Hannay, 1986) has been widely employed to investigate the effects of interference on decay in short-term memory. The procedure consists of presenting material for retention (word triad), engaging the subject in a distractor task (e.g., counting backwards) and testing recall of the material. This procedure has the advantage of extensive studies in the literature concerning the effects of task variables and findings in Korsakoff patients. Studies of the Korsakoff syndrome that employed this task disclosed a steeper decay function for word triads in amnestic patients than in normal controls or alcoholics without amnestic disorder (Butters&Cermak, 1980; Cermak, 1982, cit. in Hannay, 1986). The technique has also been used in research aimed at testing the Baddeley model of working memory (Baddeley and Lewis, 1981, cit. in Eysenck, 1995)

**Stroop paradigm**

This paradigm was first presented by Stroop in 1935 (Eysenck, 1995). In the original task, participants were presented with a sheet of color words printed in conflicting colors (word “GREEN” printed in red ink) and asked to name the colors in which the words were printed. Reaction times were measured and compared to various control conditions in which there was no conflict between the stimulus presented and the task to be performed (“XXXXX” printed in different inks, color words printed in black). The reaction times in the conflicting situation proved to be significantly longer while participants also made a larger number of errors than in control conditions. The task has since been generally adopted as a measure of the participant’s ability to respond selectively to conflicting stimuli and many variations of the original task were developed.
Dual task paradigm

Another method of testing the existence of two independent processing modules or subsystems is the dual task experimental paradigm. One can argue that if two processing tasks can be performed simultaneously without affecting each other’s performance, then the tasks must be subserved by two independent processing modules that can work in parallel. If the simultaneous performance of the tasks result in interference, one can conclude that the tasks require a use of at least one shared resource or processing component and are not independent. Dual task paradigm was used extensively in testing the Paivio (1986) dual coding theory.

Priming

Empirical evidence show that previous processing of a stimulus can lead to either faster and/or more accurate or slower and/or less accurate processing of the following stimulus. The first stimulus in such case is called a prime and the effect is called positive or negative priming. Primes can be of very varied types. Phonological priming occurs when a target word is easier to pronounce due to phonological similarity with the prime. In semantic priming, the effect is due to semantic relatedness of prime and target stimuli.

Priming has been extensively used in the study of attentional processing and mechanisms, semantic memory, language processing, implicit cognition and elsewhere. One of the most widely used forms of priming tasks is the lexical decision task in which the subject have to decide wether the taget set of characters, preceded by a priming stimulus of choice, represent a proper word or a nonword.

Cognitive neuropsychology

The goal of cognitive neuropsychology is to use existing theories of normal human cognition in explaining cognitive dysfunctions following brain damage. At the same time, it provides crucial data for testing those same theories, as well as new ideas and constrains for their development. While cognitive neuropsychology builds in large degree on presented experimental methods, it also employs a number of distinct research approaches, methods and tools.

Qualitative analysis of behaviour

In qualitative approaches to neuropsychological analysis the focus of analysis is not on the quantification of data gathered with neuropsychological test battery but on the pattern of observed behavior and strategies used in producing it. One is not as much concerned with whether problem is solved as with the way in which it is solved. The approach calls for a careful qualitative analysis of the patient’s activity, of the difficulties experienced, and of the mistakes made. Developed by Luria (Luria, 1966) it stresses the importance of qualitative analysis both at the level of behavioral observation and at the level of clinical inference.

Neuropsychological test batteries

A comprehensive neuropsychological test battery is ideally a procedure that assess all of the major functional areas generally affected by structural brain damage and describe its performance in a quantitative way. As Goldstein (1984) points out, it should be viewed as a screening instrument that screens functional areas such as memory, language, or visual-spatial skills for the effect of brain damage. Besides tests that asses impairments of specific functions, comprehensive neuropsychological test batteries should also contain tests that are generally insensitive to brain dysfunction and provide a baseline against which the extent of impairment associated with acquired brain damage can be measured.

A number of generally available comprehensive standard test batteries for adults exist. A review of the literature (Hodges, 1994; Groth-Marnat, 2000; Lezak, 1995; Nietzel, Bernstein, Milich, 1998) indicates that most frequently used are The Halstead-Reitan and Luria- Nebraska test batteries, each having its own advantages and disadvantages.

Flexible assessment approach

In the flexible approach, knowledge of the syndrome and the brain-behaviour relationships is the principal factor in determining the selection of tools. Test selection should be germane to the questions asked or hypotheses proposed. An encyclopaedic source of test data and wisdom is to be found in Lezak (1995).

Group and single-case studies

Two general approaches to research in cognitive neuropsychology can be recognized: group study and single-case study. Group study is the dominant approach in traditional neuropsychology, in which the performance on one or more tasks of a group of patients of a given type is contrasted either with the performance of another group of patients of a different type or with a group of “normal” control subjects. Group studies do provide data on the average or typical deficits and range of deficits to be expected from the groups under study, as well as data on the frequency with which certain symptoms cluster together in patients, but there are also some important drawbacks in their use for the study of underlying mental structure. A set of patients classified as Broca’s aphasics, for example, can be extremely heterogeneous with respect to the location and extent of their lesions, or with respect to the components of the system implicated. As only average scores for each group are known, much valuable information is lost in the averaging procedure and the conclusions reached may be true only for a few of the patients in the group. Definitive statements about the effects of particular lesions or unequivocal test of particular models of brain function can thus not be obtained by means of group studies (Hannay, 1986).

Single-case study approach stands somewhat in contrast to traditional neuropsychology. Advocates of the single-case approach stress that because brain damage may disrupt cognitive systems in a variety of different ways, individual differences cannot be ignored. In other words, it is not possible to be sure that any two patients will manifest the same sort of cognitive impairment even after similar naturally occurring lesions. While a reasonable compromise is to carry out a case series, the strength of the single case approach lies in its potential to reveal theoretically interesting dissociations between tasks within subjects that might appear superficially similar in a group study. Significant dissociations between symptoms have often been discovered in patients whose traditional neuropsychology has grouped together as representative of the same syndrome category (Ellis and Young, 1996).

An adequate theory of cognition should be as applicable to the individual case as to groups of individuals. Based on properly controlled experimental paradigms, appropriate methods of
statistical analysis, and carefully matched control groups, single-case studies can provide a perfectly satisfactory test of cognitive theories. When applied to rare disorders, which do not normally occur in clinical populations, important advances in our understanding of human brain function can be made.

There are also caveats to the use of single-case study. As selective impairment found in a particular task in some patient could just reflect his/her idiosyncratic strategy, a premorbid gap in that patient, or the way a reorganized system but not the original normal system operates, one must be careful at drawing theoretical conclusions about mental structure based on single-case studies (Shallice, 1988).

It seems that further developments in the field are dependent on modification of both approaches. Group studies could benefit from stricter criteria for subject inclusion and the use of more stringent statistical procedures could reduce the inclusion of atypical group members. Proponents of the single-case approach would achieve greater support if they were to take some steps towards dealing with the issue of replication. The establishment of symptoms and their explanation may become facilitated if it can be shown that deficits occur in a number of patients.

Association, dissociation and double dissociation

Another important tool in cognitive neuropsychology are the patterns of association and dissociation between observed deficits. Association of function is indicated when different patients exhibit impaired performance on the same set of tasks. If such association across task is shown, it is tempting to assume there is a common cognitive process or mechanism underlying performance on all of the tasks showing impairment. However, one must be careful as the tasks may require different cognitive processes, but these processes may be very close together anatomically, so that damage to one cognitive process is usually accompanied by damage to all of the others.

Dissociation of function occurs when two types of information processing can be distinguished (Mccarthy and Warrington, 1990). One aspect of performance is impaired whereas others are preserved, which implies the existence of separate cognitive subsystems or modules responsible for different cognitive operations. There are two types of dissociations that can be made: simple and double.

A simple dissociation occurs when a patient’s performance is normal in one task or set of tasks and poor on another set of tasks. The problem with simple dissociation is that it may not necessarily address the discontinuity between intact and impaired functions; for example, a patient might do well on one task and poorly on another simply because the other task is more difficult.

Double dissociation occurs when we find a patient that shows normal performance on task Y and is impaired on task X, and another patient that is impaired on task Y but normal on task X. In this instance, dissociation cannot be attributed to task difficulty; it is more likely that is occurred as a result of damage to discrete functional modules. In double dissociation it is not necessary for patients to exhibit impaired performances on one task and normal performances on other task; it is sufficient for performance levels to form an interaction, regardless of whether there may exist significant main effects between tasks or individuals.

This reciprocal pattern – the double dissociation – often provides the strongest evidence for a degree of independence or separability of function. Double dissociation has played an important role in providing evidence for the existence of separate short-term and long-term memory stores. Whereas some patients have impaired short-term memory but intact long-term memory, the so-called amnesic patients have severely deficient long-term memory but intact short-term memory. These findings suggest that there are two distinct memory systems which can suffer damage separately.

Conclusion

Even though providing just a brief overview of some of the research methods used in cognitive psychology, the aim of the paper was to demonstrate the width of research possibilities they provide, as well as to provide a glimpse into complexities that any student of cognition is faced with. There are no words to emphasise enough the importance of sound theoretical background in planning and carrying out any research in cognition, especially in view of ever more popular and advanced neurophysiological techniques like functional brain imaging. In Stuss’ words: “Imaging without good psychology is useless. It doesn’t tell you anything. There has been a level of explosion here, but what we know about the brain is still piecemeal” (cit. in The Globe and Mail, 2000). It is only with careful research planning and cooperation among the fields of cognitive neuroscience that future breakthroughs in understanding human mind are possible.

References