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Experimental methods in psychology and cognitive/ affective neuroscience

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Laboratory experiments have always been important in psychology and are as commonly used today as ever due to the dominating position of cognitive research in international psychology. This trend has been further strengthened by recent developments in cognitive neuroscience, where experimental studies are central. Recently, experimental studies within the field of affective neuroscience have also received attention. Notwithstanding, experimental methods remain controversial also in psychology, and one should carefully weigh their advantages against their drawbacks.

Ever since psychology emerged as a separate scientific discipline in the second half of the 19th century experimental methods have played a central, though often controversial, role in the field. For example, experiments like the infamous authority obedience experiment conducted by Milgram (Milgram 1963) as well as Zimbardo's Stanford Prison Experiment (Haney et al. 1973) have substantively added to the ethical discussions about the use and misuse of experimental methods within political psychology (e.g., Baumrind 1964). In the cognitive branch of psychology, experiments have throughout history been the primary method of investigation. Cognitive psychology deals with basic mental functions such as memory, perception, and attention, and is arguably the most fundamental branch of psychology (e.g., Bundesen and Habekost 2008, Bundesen 1990, Posner 2011). Following the „cognitive revolution" in the 1950s (for an historical account see Gardner 1985), the scientific paradigms developed for cognition research have been increasingly influential across psychology, and experimental methods are now also important in, for example, social, developmental, and clinical psychology. The methodology and general approach of experimental psychology has also been combined very successfully with neuroscience, leading to the emergence of a new and highly active scientific field: cognitive neuroscience. Recently, also affective neuroscience has received increased attention (e.g., Davidson et al. 2003, Davidson and Begley 2013, Ekman and Davidson 1994, Coan and Allen 2007). The field of affective neuroscience also draws on laboratory experiments as the main methodology to explore the affective sides of psychological processes, where a variety of subdesigns within the laboratory experimental framework are applied (e.g., Coan and Allen 2007).

In spite of its long-standing importance to many types of psychological research, the usefulness of experimental methods in psychology remains debated. In particular, there is an on-going discussion as to which psychological phenomena are suitable objects for the reductionist approach of experimental psychology (e.g., Uttal 2001). A related question concerns whether psychological and behavioral processes (including clinical disorders) are most appropriately studied at the individual or socio-cultural level. In this sense, the discussion of experimental methods in psychology also have implications for other social sciences, including political science.

This article provides a brief overview of experimental methods in psychology, including descriptions of their basic principles and illustrative examples. The article focuses on the experimental method in its most pure form, the controlled laboratory study, and discusses the validity of this scientific approach in psychology. Furthermore, it provides an account of the recent combination of experimental methods with cognitive and affective neuroscience.

Basic principles of experimental laboratory psychology

The central rationale behind the controlled experiment is the same in psychology as in the natural sciences, from where the method was taken: One seeks to isolate and manipulate specific *independent variables* in order to cause changes in specific *dependent variables*, which are then carefully measured (e.g., Wilson et al. 2010, Morton and Williams 2010). One simple example could be an experiment where a letter is shown very briefly on a computer screen and the participant's task is to report the identity of the letter (Habekost and Starrfelt 2009). In the basic version of this experiment, one investigates the relation between the length of the exposure time (the independent variable) and the probability that the participant perceives the letter (the dependent variable). In a more elaborate version of the experiment one might investigate how performance varies between participants with different psychological properties, for example, depending on age or general intelligence. Alternatively, one might consider psychological variation within participants, for example, comparing different test sessions to see how performance develops with practice (Habekost, Petersen and Vangkilde 2014). Psychological experiments are always conducted in a theoretical context, which provides guidance to the selection of independent and dependent variables, relevant hypotheses about their relations, and general interpretations of the data (e.g., Dickson 2011). The example described before might clarify aspects of visual form recognition, such as limitations in the speed of visual information processing, and how these cognitive processes interact with other factors such as the participant's age or ability to learn.

In laboratory experiments confounding influences from other factors are reduced by conducting the investigations in a highly controlled physical and social environment. The setting typically includes fixed procedures for the interaction between experimenter and participant (operationalized in a set of standard instructions), a physical environment that is approximately equal for all participants (e.g., in terms of lighting or sound levels), a systematic time course of the experiment (e.g., fully randomized or counterbalanced sequences of trials), and restricted pre-defined modes of response for the participant (Kantowitz, Roediger and Elms 2009).

This high degree of standardization brings about important advantages, but also has its drawbacks.[1] A major advantage is that the controlled procedures allow for direct replication of the results, a traditional cornerstone of good science. Given the method section from a published experimental study, it is straightforward to set up a similar study anywhere else in the world to test the reliability of the original results. This way the reliability of the findings can be checked. Another main advantage of the experimental approach is a high level of internal validity. Provided that the experiment is properly designed and conducted, one can be relatively sure that the factors manipulated in the experiment, rather than theoretically irrelevant processes, actually caused the observed changes in the dependent variables. This provides a conceptual precision that is extremely valuable for theoretical development (e.g., to devise models that distinguish sharply between different aspects of attentional function: Bundesen and Habekost 2014).

However, the isolation of particular psychological processes in the laboratory also entails a risk of reducing the phenomenon of interest to something less meaningful. The dilemma can be illustrated by an example. Suppose one is interested in visual search, the ability to locate a particular object in a visual scene. Ultimately, one is aiming to understand the psychological mechanisms involved in a complex real-life situation like looking for a particular person while standing in a busy street with many distractions. Theoretically, many different factors may influence this visual search process: particularly salient colors or forms may attract attention, the number or the location of the distracting objects may be important, prior learning experience and emotional state could also be relevant, and so on. These factors are all simultaneously active in the busy street, which makes it very difficult to conclude something specific from observing people's behavior in this situation.

The experimental approach offers a way of disentangling the influence of all these factors by singling out particular ones for study in the laboratory. For example, the influence of color can be studied by varying this factor systematically, while keeping all other factors constant. In another line of experiments, one might instead focus on the influence of emotional states, and so on. The question is then to what extent results obtained in the laboratory can be integrated with each other and generalized back to the real-life situation; whether the experimental study has „ecological validity" (Morton and Williams 2010, 253-275). This is generally difficult to determine, as one can-not merely rely on a superficial impression of whether the experimental task „seems similar" to the real-life process or not (whether it has „face validity"). In some cases, one might have relevant evidence to estimate the ecological validity of the measure, for example if there is a reliable relation between an experimental test score and some measure of real-life performance (e.g., the ability to drive a car safely). However, such evidence can be ambiguous and in many cases simply be lacking.

A different approach is to assume that psychological *theories* provide the necessary ecological validity, since they address general psychological mechanisms. In this view, the purpose of laboratory experiments is not to mimic real-life situations, but to test particular predictions of theories. Because the theories have general scopes and should hold across many situations, it should also be possible to falsify or confirm their predictions in a laboratory setting. From this perspective, it matters less that an experimental task may seem to be a reduced version of the phenomenon in question, because the laboratory findings can still test the validity of a theory that speaks to general psychological questions.

Another fundamental question in experimental psychology concerns whether to investigate a few individuals in great detail or rather to examine large groups of people by more coarse measures. If a psychological process is assumed to function in a highly similar manner across healthy adult individuals (for the uniformity hypothesis see Coltheart 2002), it makes good sense to investigate its details very precisely in a small group of participants, and then generalize the findings to the whole population. This is, for example, often assumed for basic sensory processes, where individual participants are typically investigated very extensively for detailed analyses of their perceptual mechanisms (e.g., Petersen and Andersen 2012). The case-based approach is also common in more applied parts of psychology, for example in cognitive neuropsychology, where many of the great discoveries on brain-behavior relationships were originally based on studies of single patients with brain damage. For example, the fundamental role of the hippocampus for memory processes was first revealed by studies of patient H.M., who suffered a severe memory loss after his hippocampus was operationally removed in both sides of the brain (Scoville and Milner 1957). Such neuropsychological findings have since been confirmed in many individuals, and generally one seeks to combine the analytical depth and precision of single case studies with the representativeness obtained by studying large groups of people.

Two examples: accuracy and response time in psychological experiments

The two main dependent variables (outcome measures) used in experimental psychology are *accuracy* and *response time* (Ashcraft and Radvansky 2013). The outcome measures often have limited interest in themselves, but represent ways of testing models of the underlying psychological processes. In more advanced cases these psychological models take mathematical form, which enables highly specific hypothesis testing. Starting with accuracy, this is a measure of the correctness versus failure of a particular mental process. As an example of an accuracy based experiment, consider a task where six unrelated letters are flashed on a computer screen for a brief period of time (e.g., 50 ms). The participant's task is to report as many of the letters as possible (*whole report*; Habekost and Starrfelt 2009). If the task is repeated a sufficient number of times, and the exposure duration is systematically varied from near-threshold to ceiling performance, the mean number of correctly reported letters (i.e., accuracy) develops as a function of exposure time in a characteristic fashion: At very low exposure durations accuracy is zero, then the score starts to rise abruptly, followed by a gradual leveling of the accuracy curve to approach an asymptotic maximum that is typically between three and four letters. Shibuya and Bundesen (1988) showed that this performance pattern can be very closely modeled by an exponential function that includes three parameters: the visual processing speed C, the storage capacity of visual short-term memory K, and the perception threshold $t0$. The original analysis of Shibuya and Bundesen was based on many hours of testing just two participants, but has since been validated in numerous studies involving thousands of people, also individuals with brain damage or psychiatric disturbances. The processes involved in the whole report task can be understood by a general model of attention (the TVA model is found in Bundesen 1990, Bundesen and Habekost 2008), where selection of visual information for conscious perception is viewed as a race between all elements in the visual field, and capacity limitations such as the C and K parameters are crucial for the outcome.

The other main dependent variable in experimental psychology, response time, represents a sum of all processes between stimulus and response. Typically one is not interested in the overall response time but rather in how specific psychological processes contribute to certain parts of it. To reach such conclusions, sophisticated designs and analysis of the experiments are necessary. Sternberg (1969) developed an experimental design that is regarded as a classical example of response time analysis. As in the previous example, the experimental task is simple (Sternberg 1969). The participant must memorize a small set of letters (either 2, 3, 4, or 5 items), this time shown for so long time on the computer screen that perceptual limitations are not a problem for solving the task. The letter set is then held in mind and followed by a probe letter on the screen. The task is simply to determine as rapidly as possible whether the probe letter was in the memory set (which is the case for 50% of the trials, randomly intermixed). This task requires efficient mental search of the items held in mind, and the purpose of the experiment is to elucidate the way this search process is carried out. It turns out that the mean response time is a strictly linear function of the number of letters in the memory set. Sternberg interpreted this as evidence that participants mentally search through the memory set in a *serial* fashion, that is one letter at a time, rather than process all letters in the memory set simultaneously to determine if there is a match to the probe.

This serial search hypothesis is consistent with the fact that response time increases with a constant number of milliseconds for each item in the memory set (i.e., linearly). Further, Sternberg noted that the slope of the linear function was similar regardless of whether the probe was in the memory set or not. Sternberg took this as an indication that, contrary to intuition, the mental search is performed in an *exhaustive* rather than a *self-terminating* manner. That is, the participant continues the mental search of the memory set even though the probe letter is recognized during the process, and therefore the search is not performed any faster if a match is present or not. These very clear results have been replicated numerous times, although other psychological mechanisms than described in Sternberg's original model have since been proposed to account for the pattern of response times.

Unfortunately, these elegant mathematical models are seldom able to account for more complex psychological processes where strategic factors, such as choices between different ways of solving the task, and response complexity (e.g., hundreds of eye movements during a search task) produce so many degrees of freedom that the performance pattern can no longer be modeled with mathematical precision. However, such psychological processes can still be modeled in more general, qualitative terms, and these models can also be subjected to hypothesis-based experimental testing.

Experimental psychology and cognitive neuroscience

The experimental approach to psychological processes has its roots in the natural sciences. It is therefore no wonder that it is highly compatible with the most relevant parts of the natural sciences, namely the neurosciences, which study the biology of the brain (e.g., Gazzaniga et al. 2009). In the field of cognitive neuroscience combined measurements are made of behavioral performance on a psychological task and some brain property, for example, blood flow in specific regions of the cortex (Jezzard, Matthews and Smith 2001), electrical activity in large populations of neurons (Luck 2005), or the anatomical location of a brain lesion (Damasio and Damasio 1989). This way one can obtain direct correlations between a well-defined psychological process (isolated by the experimental task) and particular aspects of brain function. The scientific power of this cross-disciplinary approach has become very evident in the last few decades, where the neural correlates of more and more psychological processes have been put under scrutiny by sophisticated technical methods: magnetic resonance scanning of blood flow patterns, mathematical modelling of electrophysiological activity in the cortex, magnetic and electric stimulation of particular brain areas, and many more (e.g., Purves et al. 2013). This has led to many remarkable discoveries about how basic mental processes depend on specific parts of the brain. For example, measurements of single neurons in the visual cortex have shown that changes in their electrical activity with different attentional states can be described using the same mathematical equations that apply to the psychological behavior of the whole organism (Bundesen, Habekost and Kyllingsbæk 2005).

The scope of these mind-brain investigations, which initially focused on elementary cognitive processes (e.g., visual perception) have widened greatly in recent years and now include topics drawn from all over the humanistic and social sciences. For example, inspired by the scientific success of the core parts of cognitive neuroscience, researchers are now studying the neural basis of phenomena as diverse and psychologically complex as religious beliefs (e.g., Haidt 2012), aesthetic experiences (dio Cinzia and Vittorio 2009), and electoral voting patterns (Amodio, Jost, Master and Yee 2007). Empirical progress has, however, been more limited in many of these fields, raising the question of how far the cognitive neuroscience paradigms can be applied. Central to this discussion is the question of what mental and behavioral processes can be captured by the highly individualistic approach of the controlled psychological experiment.

Experimental psychology and affective neuroscience

Recently, experimental research has also been widely used within the emerging field of affective neuroscience (e.g., Davidson et al. 2003, Davidson and Begley 2013, Ekman and Davidson 1994, LeDoux 2003). As a sign of this trend, the American Psychological Association in 2001 founded a scientific journal aiming at affective research called *Emotions.* Along similar lines as in cognitive neuroscience, the study of affective psychological processes has also benefitted tremendously by merging it with the latest findings from neuroscience. It is important to note that affective science is more than mere studies of emotions. Affective science distinguishes between six major affective phenomena and encompasses *emotions, feelings, moods*, *attitudes*, *affective styles* and *temperament* (Scherer and Peper 2001). Yet, importantly, these six affective phenomena are to be understood as a catalogue of the most frequently study areas within affective science, not an exhaustive list (Davidson et al. 2003, xiii).

Similarly, cognitive and affective neuroscience are also not to be understood as separate sciences. The distinction between affect and cognition dates back to Plato's philosophical discussions, where he understood emotions to be in direct opposition to cognition. Yet, recent research has shown that the two processes rather should be seen as complimentary than as adversaries. And, increasingly, psychological experimental research explores the interaction between cognition and emotion to study the dynamics of, for example, the processes of memory, judgment and decision-making (e.g., Scherer 2003, 563). The exploration of interactions between affective and bodily processes were pioneered and popularized by Antonio Damasio, who challenged two central tenets within neuroscience; first, the tendency to study the brain and body separately, and, second, the predominant understanding of rationality as something separate and distinct from emotions (Burkitt 2014, 79, Damasio 1994).

These ontological insights have provided the basis for a new research agenda, focusing not only on the exploration of affective processes in themselves, but also providing grounds for studies on the interaction between affective and cognitive processes. These studies have provided insights into the role of emotions on, for example, attitudes and judgments (e.g., Forgas 2003) as well as the role of emotions in decision making (e.g., Loewenstein and Lerner 2003) to mention a few examples. Central to these findings are their added value in a political science perspective, as they shed light on the role of emotions when individuals make political decisions or interact in the broader political society. Still, in order to generalise these findings to broader political and/or societal discussions, which characterises political science as an academic field, we also need to explore these individual level affective processes in a social and contextual perspective.

Individual versus social perspectives on psychological processes

The perhaps most common criticism of experimental psychology holds that it is problematic to study humans independently of cultural and social context, as it is attempted in the controlled laboratory setting. This is, for example, a central statement of the so-called critical psychology movement, which was founded in the 1970s and draws heavily on Marxist theory (e.g., Holzkamp 1983). Critical psychology was quite influential in Danish psychology in the last decades of the 20th century, whereas the impact on international psychology has been limited. Regardless of the relevance of Marxist perspectives in psychology, the general point about the importance of socio-cultural factors on human behavior remains important and has also been advocated from many other sides in the social sciences (e.g., Heine 2010).

While it is obvious that human beings are inherently social, and that cultural influences are pervasive in our lives, it seems equally clear that many psychological processes, for example our abilities to perceive, think, and remember, can be meaningfully studied at the individual level. The remarkable empirical progress achieved in cognitive and affective neuroscience also bears witness to the fact that (at least some) psychological processes can be well studied at the level of the individual organism. Still, one of the most important roles of psychological processes is *„…their regulatory function in relationships, social interaction, and group organization..“* (Davidson et al. 2003, xiv). Or, in brief, their relevance for the sociopolitical environment in which the studied phenomena take place.

Within the recent explorations in psychology and neuroscience, there have been attempts to include the social aspect of affective phenomena with the development of the nascent field of social neuroscience (e.g., Cacioppo et al. 2000, Lieberman 2007, Heatherton and Wheatley 2010). This is where cognitive and affective neuroscience becomes relevant for political science. The core of political science is defined by the study of phenomena relevant to understand the political system and society – i.e. the interaction between individuals in a broader societal setting, and with the particular focus to understand the occurrence of politically relevant phenomena better. This has been the aim of social psychology for many years, for example, when exploring intergroup relations (e.g., Tajfel 1982). With the introduction of neuroscience into the fields of affection and cognition, experimental methods have reached a new cross-disciplinary way to provide insights into the psychological dimensions of political science.

Thus, rather than arguing about the necessity of socio-cultural perspectives on psychological processes in general, it seems more fruitful to evaluate the matter relative to each particular phenomenon one wants to study. When we are dealing with elementary mechanisms of cognitive functions such as perception, attention, and memory, which seem to depend on brain circuits that are common to all members of the human race, the individually oriented perspective of experimental psychology is on firm grounds. It is less clear how the influence of cultural differences and social context can be handled for some of the more complex processes that have recently entered the focus of experimental psychology and cognitive or affective neuroscience. Is it, for example, justified to investigate a person's social behavior and preferences in a magnetic resonance scanner, where the person lies immobilized and alone while carrying out a task that is entirely determined by the experimental design? In cases such as these, one should be careful to weigh the advantages of the rigorous experimental method against the drawbacks of its reductionism.

Conclusion

Unlike mainstream political science, laboratory experiments have been a core tool in psychological research for many decades. Though experiments as a method are not without serious shortcomings and pitfalls, they simultaneously provide insights into psychological processes that are hard to observe using other kinds of methodologies. This article has accounted for the basic rationale behind laboratory experiments in psychological research as well as pointed to the reductionist pitfalls inherently present in the individual level experimental measurement. Furthermore, the article has described recent developments in the field of cognitive neuroscience as well as the even newer evolution of the field of affective neuroscience. We have emphasised that the current tendency to combine findings from neuroscience with psychological research has provided new and pioneering knowledge, also to the psychological fields of most interest to political scientists. Yet, we urge researchers to remain aware of the limitations of experimental methods and not limit their conclusions to the individual perspective.

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