

Experimental Paradigms and Their Knowledge Associations in Studies of Information Processing: A Review

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ABSTRACT

Experimentation is the foundation of empirical science and is an important research method of mental cognition. The experimental paradigm, as an important part of experimental research method, is a relatively fixed task program, which is mainly used to describe certain psychological phenomena clearly and accurately. However, the application of experimental paradigms is characterized by mixed task content and complex paradigm type. This paper reviews typical experimental paradigms which are used to study information-processing such as perception, attention, working memory and long-term memory, in terms of paradigm origins, task procedures, research results and development. Based on the review of various experimental paradigms, the knowledge relevance between them are further sorted out in the aspect of task procedure characteristics and research trend. It provides reference for the application and design of experimental paradigms in studies of information processing.

Keywords: Experimental paradigms, Information processing, Knowledge associations, Program features

INTRODUCTION

Psychology is a discipline that studies psychological phenomena and their laws. From the perspective of psychological research method, the research routes of different psychological schools are mainly divided into Objective-experimental Paradigms and Subjective-Experiential Paradigms (Che, 2003). The objective-experimental paradigms utilize experimental and observational methods to acquire objective knowledge of psychology, which advocate the objectivity and positivity of psychological research methods (Peng, 2008). Researchers have designed numerous experimental paradigms based on objective experimental research methods, which play a crucial heuristic and theoretical role in basic psychological research.

THE SOURCE AND DEVELOPMENT OF OBJECTIVE-EXPERIMENTAL PARADIGMS

The objective-experimental paradigm is a theoretical model of scientific psychology based on positivism in mainstream Western psychology, which believes that psychology can obtain objective knowledge about human psychology and behaviour through objective empirical methods. The objective-experimental paradigm originated from the study of behaviourism, establishing stimulus-response paradigms including observation, conditioning, oral reporting, and testing (Li, 1997). However, this type of paradigm completely denies the existence of consciousness, and the S-R model used to explain behaviour does not conform to the actual laws of human behaviour. With the rapid development of computer science, the information processing paradigm with the main goal of exploring the internal psychological mechanisms has emerged, which transcends the limitations of the stimulus-response paradigm and fully reflects the comprehensive research characteristics of psychology based on experiments. The information processing paradigm believes that the process of obtaining, storing, processing, refining, and applying information involves cognitive activities such as sensation, perception, memory, attention, representation, thinking (Solso et al., 2019). Due to the difficulty in observing psychological processes, it is necessary to rely on experimental methods to design stimuli (input) and responses (output) to infer the internal processes of psychology. These experimental methods are specifically manifested as fixed task program experimental paradigms, used to describe and express certain psychological phenomena clearly and accurately, as well as test certain hypotheses or newly proposed concepts (Chen, 2017).

This paper analyses task design, research objectives of typical experimental paradigms based on the different stages of information processing, such as perception, attention, and memory.

PERCEPTION EXPERIMENT PARADIGM

Perception is a high-level cognitive process that explains sensory information (Zhu, 2016). Typical experimental paradigms include visual search experiment, priming paradigm, negative priming paradigm, and global-local paradigm.

Visual Search Paradigm

The visual search paradigm requires that target and distractor are presented simultaneously. Participants extract the target from a large amount of information and respond according to the task. The material is usually in the form of pictures, letters, etc., and is presented in three types: clutter, matrix, and circle (see Figure 1). Treisman (1980, 1985), Theeuwes (1991), Bacon (1994), Luck (1994), Wolfe (2003), et al. have used the visual search paradigm to study feature integration theory, automated processing theory, and guided search models in the areas of perception.

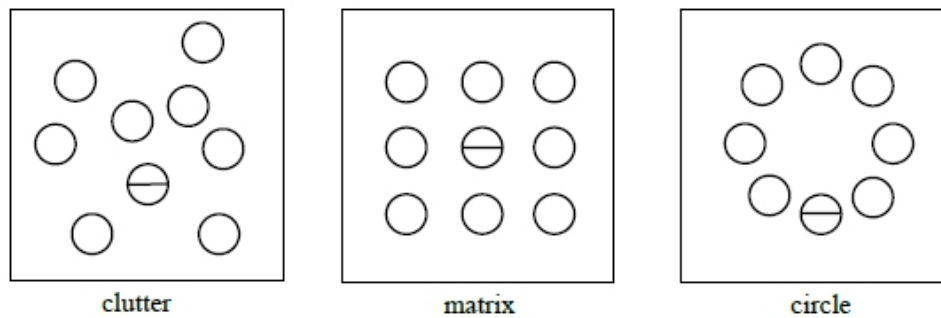


Figure 1: The arrangement types of visual search paradigm.

Priming Paradigm

The priming paradigm is an experimental task that studies unconscious processing at the perceptual level, by presenting the priming stimulus to the participant in advance and then presenting the probing stimulus to generate the priming effect. A word-identification task designed by Meyer (1971). The process involves two phases: prime display and probe display which presenting two stimuli separately, participants need to determine whether the stimuli in the probe display are non-word or word. If the words are the same or related between the prime stimulus and the probe stimulus, the response time of participants is significantly shortened. Marcal (1983) designed a masking priming paradigm and found that the priming effect can still occur even after the detection word is masked.

Negative Priming Paradigm

Negative priming can reflect the operation of non-target stimuli. The task consists of two sequentially display of stimulus (prime display, probe display), both of which contain target and distractor. The task is to require participants to determine the target item of the stimulus while ignoring the interference item of the stimulus. The experimental design showed that the target in the probe display was the same as the distractor in the prime display, resulting in a delay in the response to the target, which known as negative effect (Houghton and Tipper, 1994; Tipper, 1985; Tipper and Cranston, 1985).

Global-Local Paradigm

Navon (1977) designed a global-local paradigm to investigate visual information processing, which advocates the primacy of information about the overall pattern or structure. This paradigm uses the letters “H”, “S”, and “O” to design a composite stimulus that forms a material with both local and global features (see Figure 2). The experiment was divided into the conditions of consistency and inconsistency between local and global features, and participants were required to discriminate between local and global features of the material. Miller (1981), Robertson (1993) used this paradigm to investigate the global priority theory of visual perceptual processing.

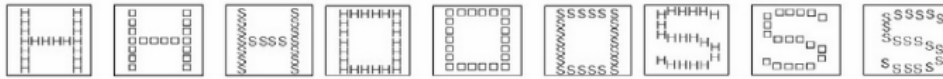


Figure 2: Example of a global-local paradigm stimulus (Navon, 1977).

ATTENTION EXPERIMENT PARADIGM

Attention is the concentration of sensory or psychological events, with the functions of selection, orientation, amplification, inhibition, and allocation. Typical experimental paradigms include Stroop paradigm, Simon paradigm, Flanker paradigm, spatial cueing paradigm, multi-target tracking paradigm, and rapid serial visual presentation paradigm.

Stroop Paradigm

The American psychologist Stroop (1935) discovered the Stroop effect in a colour-naming experiment in 1935. The experimental stimuli were word “green” displayed in red colour (colour and meaning were different) and word “red” displayed in red colour (colour and meaning were same). Participants were asked to report what word was on the screen. It was found that the response time was shorter at the condition of congruent than for the condition of contradictory (Hermans et al., 1999; Egner et al., 2008).

Simon Paradigm

The Simon paradigm was proposed by Simon and Rudell (1967), mainly manifested as conflicts between target features and reaction positions. Participants are required to press the left button when they see red, while ignoring the spatial position of the colour presentation (see Figure 3). The performance of participants is better when the position of stimulus and response appear on the same side compared to the opposite side, which is known as the Simon effect.

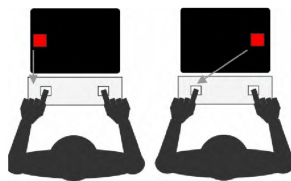


Figure 3: Example of Simon paradigm.

Flanker Paradigm

Flanker paradigm, proposed by Eriksen and Eriksen (1974), is one of the basic paradigms for studying inhibitory control, conflict processing, and perceptual load (Paquet et al., 1997; Chanceaux et al., 2013; Myriam et al., 2014). stimulus usually consist of a central target and some distractors

located on both sides of the target. Two types of flankers (compatible, incompatible) were included in the experiment to attract attention (see Figure 4). Participants need to respond to central stimuli and ignore bilateral stimuli. It leads to a phenomenon of slowed response and increased error rate when the central target is different from the bilateral distractor, which is called the Flanker effect.

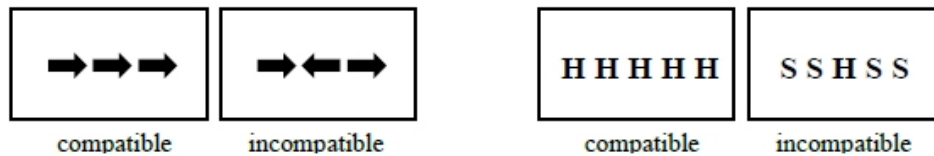


Figure 4: Example of flanker paradigm stimulus.

Spatial Cueing Paradigm

The spatial cueing paradigm is a typical experimental paradigm for studying spatial attention orientation and spatial attention capture ability (Eriksen et al., 1986; Egly et al., 1994; Sahan et al., 2015). Posner (1980) designed peripheral cues and central cues to guide spatial attention. The experiment was divided into two stages: prime and probe. During the prime phase, participants were given two types of cues: central cues which in the centre and peripheral cues which at either side. The task is to determine the target position and respond during the probe phase.

Multi-Target Tracking Paradigm

The multi-objective tracking paradigm is mainly used to study the attentional processing of visual information in dynamic scenes. During the prime phase, some stimuli are labelled as targets, while others are distractors. In the probe phase, all objects perform independent and random movements. The participants are required to track the target and report whether a certain object is the target phase after the movement (Pylyshyn and Storm, 1988).

Rapid Serial Visual Presentation Paradigm (RSVP Paradigm)

The RSVP paradigm is a typical experimental paradigm for studying attentional detachment, where the stimulus sequence contains two targets (T1, T2) and distractors. The duration of stimulus presentation is limited, usually presented sequentially at the same position in the speed of 100 ms of each. Participants need to identify whether they can perceive target T1 and T2 (Potter, 1976; Raymond et al., 1992).

MEMORY EXPERIMENT PARADIGM

Researchers explored the memory functions of encoding (memory), storing (retention), and extracting (recall and recognition). Typical experimental paradigms include change perception paradigm, recall reporting

paradigm, N-back paradigm, change detection paradigm, associative recognition paradigm, and Deese Roediger McDermott paradigm.

N-Back Paradigm

N-back paradigm originated from Kirchner's (1958) research about working memory of continuous processing ability. It refers to asking the participant to compare the current stimulus with the n^{th} to last stimulus and press a button based on the comparison result (Watter et al., 2001; Pergher et al., 2019; Wang et al., 2019). According to the location of the target stimulus in the current N-Back task, it can be named 1-Back, 2-Back, and 3-Back tasks to distinguish task difficulty. There are typical examples of letter matching and position matching tasks in the N-Back paradigm (see Figure 5).

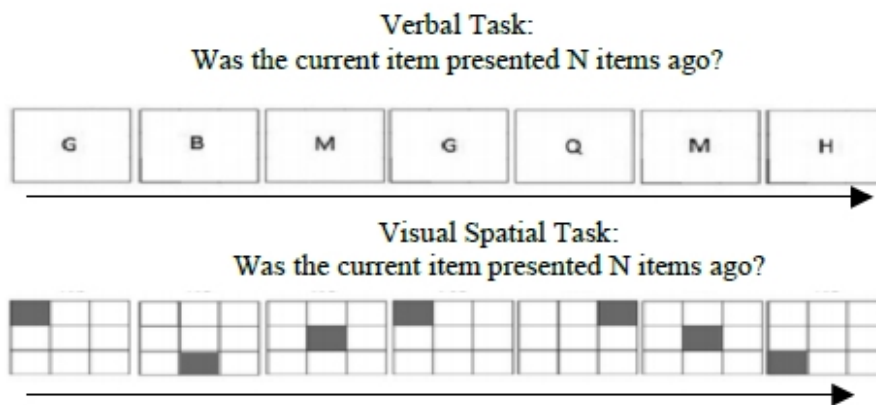


Figure 5: Example of N-back paradigm.

Change Detection Paradigm

Change detection paradigm first appeared in Phillips's (1974) research of sensory storage and short-term visual memory. The characteristic of this paradigm is the formation of short-term visual memory through manipulating Inter stimuli interval (ISI). Presenting one or a set of targets to the participants in the phase of memory. Then, the screen only presents the background colour without any visual information. In the detection stage, one or a set of visual stimuli are presented to the participants again, requiring them to determine whether the detection item is the same as the target. Phillips (1977), Luke (1997, 2001), Vogel (2001) explored the storage and capacity issues of visual working memory by using the change detection paradigm.

Associative Recognition Paradigm

The associative recognition paradigm was first proposed by Humphreys (1976) to study associative memory in long-term memory. Its characteristic is that the items that need to be learned and remembered appear in pairs

(such as A-B; A-colour of A; A-b). Participants are required to correctly recognize paired items and their relationships during the testing phase after memorizing.

Deese Roediger McDermott Paradigm

Deese (1959) designed Deese Roediger McDermott (DRM) paradigm by utilizing semantic associations between old items and critical lures to induce erroneous memory. For example, participants first learned a series of words (such as toast, butter, jam, butter, Dim sum, milk), which were semantically related to a Critical Lure (such as bread). During the detection phase, participants were randomly presented with old item, critical lure, and unrelated item. The participants need to determine whether each word has appeared during the encoding stage. The results showed that the participants had a significantly higher false memory rate for critical lure than for unrelated item (Roediger and Mc Dermott, 1995; Kurkela and Dennis, 2016).

CONCLUSION

The experimental paradigm plays an important and practical role in solving possible explanatory problems in psychological research, and in promoting the development of a unique scientific methodology in cognitive research. Psychological research can be considered as examining the impact of two (or more) psychological construct on another psychological construct (Meiser, 2011). A large number of studies use experimental paradigms to hypothesis verification or theoretical empirical research. The composition of the experimental paradigm requires attribute settings such as variable type, variable ranking, display time, and number of experiments. Therefore, attribute setting and research theory are an integral and interrelated part of the experimental paradigm (see Figure 6).

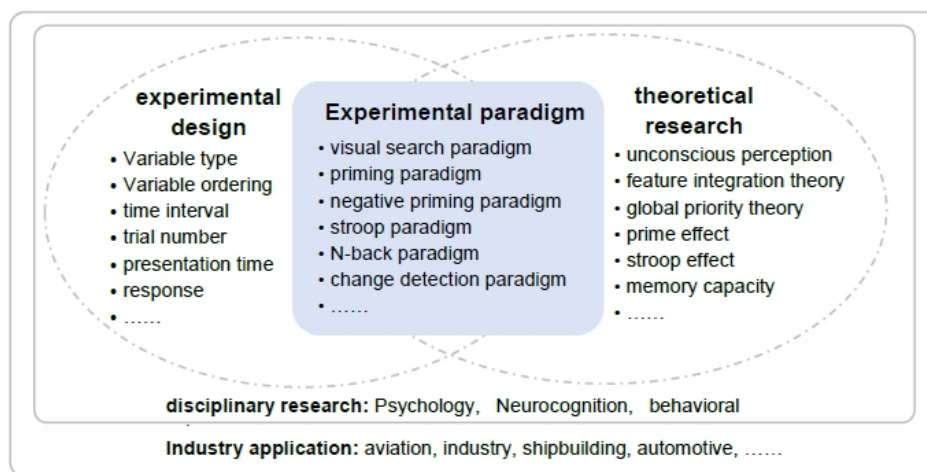


Figure 6: Experimental paradigm knowledge association.

It can be observed that some experimental paradigms have similarities in program design (independent variables, task flow, etc.), partly because they are used to validate the same theory or hypothesis. For example, Stroop paradigm, Simon paradigm, and Flanker paradigm all conduct attention research by designing conflicts between target stimuli and interfering stimuli (Ridderinkhof et al., 2004). On the other hand, some paradigms have heuristic value and contribute to the emergence of new theoretical and empirical methods. Griffin (2003), Landman (2003) applied the change detection paradigm to study and found that participants who provided clues during the working memory retention stage performed better. Subsequent research scholars drew inspiration from the spatial cue design paradigm to study the post cue effect in working memory.

A large number of experimental paradigms were designed from the 1950s to the end of the 20th century, which not only contributed to the development of psychological research (Anderson et al., 2021; Schoth and Lioffi, 2017), but also advances other disciplines such as neurocognition (Janapati et al., 2022), behavioural science (Lange, 2022), and psychopathology (Bujarski and Ray, 2016). The experimental paradigm lays the theoretical foundation for exploring the essence of information acquisition, processing, storage. Moreover, the experimental paradigm combined with disciplinary research has been widely applied in various industries such as aviation, industry, shipbuilding, automotive, which are able to improve human-machine efficiency and promote industry development.

The visual search paradigm is a research methodology that explores how individuals identify and locate specific targets in a range of distractors. We used this paradigm to investigate the effects of flicker and other dynamic highlighting on the visual cognitive performance of nuclear power operators. Participants were presented with displays containing both target and non-target. Then they were instructed to look for the target while ignoring the distractors. The results of the experiment demonstrated that certain flickering characteristics, such as a specific frequency and position, significantly influenced attention capture and visual search performance. This understanding has implications for a wide range of applications, from enhancing the usability of interfaces to improving the effectiveness of visual displays in high-stakes environments like nuclear power control systems. Overall, the visual search paradigm provides a powerful tool for exploring the complexities of visual attention and cognition, enabling researchers to gain insights into how individuals respond to visual information.

ACKNOWLEDGMENT

This work was supported by State Key Laboratory of Nuclear Power Safety Monitoring Technology and Equipment (K-A2021.419), the National Nature Science Foundation of China (52175469), and Jiangsu Province Nature Science Foundation of China (BK20221490).

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