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Review article

A review of the 5-Choice Serial Reaction Time (5-CSRT) task in different vertebrate models

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ABSTRACT

Within cognitive and behavioural research, the 5-Choice Serial Reaction Time task is widely recognized as a valuable test of attention in rats. However, technical and methodological developments required for extending its usefulness are still at an early stage. In view of advances in knowledge about cognition and other areas of biology, issues surrounding attention are increasingly important, and appear to require new methodological approaches. These changes may concern (i) the evolution of the protocol itself, (ii) adaptations in how tasks are implemented (e.g. use of new technologies such as touchscreens), and (iii) applying existing tasks to species presenting an emerging potential. From a primarily methodological perspective, this review focuses on work that has successively built upon the original 5-CSRT task. We address the strengths and weaknesses of new approaches as well as some of the new possibilities they offer.

Contents

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1. Introduction

In behavioural studies, especially in animal models, the specificity of a measure is a particularly important consideration when selecting an experimental protocol. According to Bushnell (1998): " The specificity of a procedure for a process is determined by the degree to which the outcome of an experiment with the procedure reflects a change in the process of interest, and not a change in some other biological system". It is difficult to imagine a behavioural procedure that would be absolutely specific and selective for a given cognitive function. Although many experimental protocols are both highly simple and standardized, behavioural tasks always involve other cognitive, sensorial, sensorimotor, physiological or physical processes. The case of attention is even more complex because current cognitive psychology recognizes several aspects (or subcategories) of attention processes (i.e. selective attention, divided attention, orienting attention or sustained attention), which are closely interrelated; this applies to both humans (Posner and Petersen, 1990) and animal models (Bushnell, 1998). Thus, one may define as 'specific' a behavioural test that both allows to target more particularly one aspect of attention, and to determine if behavioural changes (i.e. performance) reflect a change in the function of interest rather than confounding factors (e.g. visual or motor troubles, variation of motivation...). Many behavioural tests have been proposed to study attention, but few have been clearly associated with a specific attentional process in animals (for review: Bushnell, 1998).

One method consists of observing non-conditioned behaviours. For example, Welner and Koty (1993) used "head scanning" movements in rats as an indicator of general alertness in response to visual stimuli, and Defolie et al. (2015) used body and head direction to measure monkeys' attentive behaviours. A second approach consists of quantifying a subject's proximity to an object or area of interest. This approach focuses on the animal's exploratory behaviour, in which attention is a key element. It has been used in fish (e.g. Burns, 2008), and more rarely in rodents (Anderson, 1994). Although these methods are simple, fast and economical, they do not reveal the attentional processes involved.

A second, more frequently used method involves standardized test protocols requiring prior learning through operant conditioning and that incorporate variable parameters. Often, such protocols were initially developed in humans then transposed to animal models through adapted experimental devices. In this context the quality of the experimental model increases when performance patterns of subjects (e.g. following parametric manipulations of the task, pharmacological or brain lesion interventions) are consistent with data observed in humans.

One such example concerns a protocol that was developed to specifically study a central attentional process called "covert orienting" in humans. In this task, a subject fixates a central point on a screen and then responds as quickly as possible to a stimulus that appears in the darkened visual field, based on sensory cues provided prior to the stimulation (for review: Posner and Petersen, 1990). Such a protocol was adapted for monkeys (Bowman et al., 1993; Voytko et al., 1994), then rodents using a variant that did not require the control of visual fixation (Bushnell, 1995; Ward and Brown, 1996). These studies generally revealed appropriate effects of parametric manipulations, indicating that cued target detection in monkeys and rodents could provide a valid model of covert orienting in humans (Bushnell, 1998).

A second example concerns a protocol classically used to study attentional flexibility. This component of attention plays a major role in attentional processes by enabling a reorientation of resources towards particular information in the environment. A widely used test of cognitive flexibility in humans is the Intra-Dimensional/Extra-Dimensional set-shifting task (e.g. Chamberlain et al., 2011), directly inspired by the Wisconsin Card Sort Task (Grant and Berg, 1948). This task has been successfully transposed to monkeys (e.g. Dias et al., 1996a,b; Moore et al., 2005; Roberts et al., 1988), rats (e.g. Birrell and Brown, 2000; McAlonan and Brown, 2003), and more recently to mice (Bissonette et al., 2010; Bissonette et al., 2008; Garner et al., 2006). Results have shown that the neural structures controlling switching of attention within the same dimension and between different perceptual dimensions appear similar in humans, monkeys, rats, and mice (for review: Barnett et al., 2010).

A final example concerns the "Signal Detection Task", a protocol that aims to study temporal components of attention. It is based upon signal detection methods originally used for testing vigilance abilities in humans (Parasuraman and Giambra, 1991). In the classical protocol developed for rats, a subject monitors a panel that has a unique central target (i.e. light) and two levers, one to the left and one to the right of the target. During a trial, the subject has to press one lever according to whether it has detected the presence of a visual stimulus (signal trial) or not (blank trial). This protocol has been used in rats to elucidate neurobiological substrates (e.g. McGaughy et al., 1996; Sarter et al., 2005) and neurochemical pathways (Bushnell et al., 1997; Nelson et al., 2002; Rezvani et al., 2009) associated with attentional processing. Interestingly, the conventional process of transposition between species has been inverted, as the "Signal Detection Task" has subsequently been transposed from animal models to humans. (Bushnell et al., 2003). Results suggest that this method assesses similar attention and decision processes in rats and humans; however, it is still not entirely clear that it measures vigilance as in original human tasks. In particular, the regular and high frequency of signal presentations and the need to manipulate levers seem incompatible with the requirements of a vigilance task (Bushnell, 1998). The protocol has recently been used in mice using an optimized device (St. Peters et al., 2011), with results showing performance comparable to that of rats tested using largely similar task parameters.

The few examples given above represent commonly used protocols to study attentional processes in animal models; they do not give a comprehensive picture of the numerous behavioural pro-