

Implementing a random dot kinematogram

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PERCEPTUAL decision making research investigates the mechanisms underlying the choice of one option from a set of alternatives when the decision is based on sensory information. Some real life examples include deciding while driving a car whether a stimulus on the road is an animal or the shadow of a tree, or at a party whether the word that someone is shouting is my name or a different word, or while hiking deciding as quickly as possible whether a rock is falling towards me or has a different trajectory. In the situations described, the decision maker has to make a choice regarding a noisy stimulus (i.e. an ambiguous stimulus) by accumulating perceptual evidence supporting the different alternatives (i.e. animal vs. tree, my name vs. another word, towards me vs. another direction), until a decision is made in favour of one of the two options. In the laboratory, perceptual decisions are usually studied by visually presenting noisy stimuli that participants are required to classify using one of two opposite responses (e.g. 'left' vs. 'right', 'big' vs. 'small'; Bogacz et al., 2006).

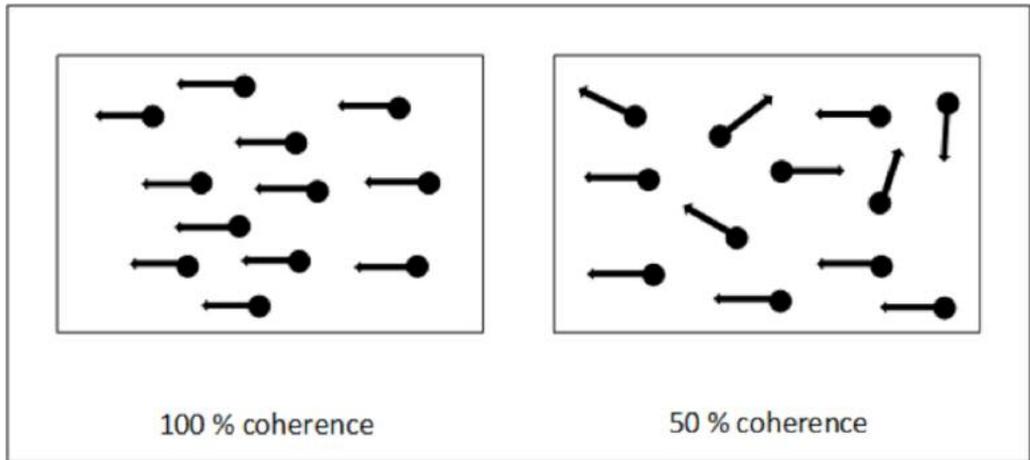
In a perceptual decision making task known as random dot kinematogram (RDK), the decision maker is asked to identify the direction of a coherent subset of moving dots on a computer screen by pressing a button on the keyboard. Typically, a percentage of dots move randomly (noise dots) while the remaining dots (signal dots) move in a coherent direction (Ball & Sekuler, 1982; Shadlen & Newsome, 2001). A schematic representation of RDK stimuli is shown in Figure 1. A huge variety of RDK tasks have been used and this experimental paradigm has been tremendously fruitful in the explanation of

different phenomena in fields such as (but not limited to) motion perception (Britten et al., 1992), perceptual decision making (Gold & Shadlen, 2007) and perceptual learning (Ball & Sekuler, 1982). In perceptual decision making research, experiments based on RDK stimuli have provided insight into understanding some of the underlying mechanisms and principles; from the description of computational models of perceptual decision making (Bogacz et al., 2006) to the neural mechanisms of simple perceptual decisions (Shadlen & Newsome, 2001).

Usually in an RDK task the decision maker is asked to decide between two alternatives and this procedure is defined in the literature as a two alternative forced choice task (Bogacz et al., 2006). In an interrogation paradigm participants should make a decision when presented with a cue, while in a free response paradigm participants can make a response in their own time (Bogacz et al., 2006).

In decision-making research, the experimenter can vary different critical parameters according to the aim of the investigation in order to affect the decision process of the participant. By way of example, one important parameter is the difficulty of the task; by varying the proportion of coherently moving dots the experimenter can manipulate the difficulty of the task. A consequence of the difficulty is that easier conditions will result in fast reaction times and few errors while difficult conditions result in slow reaction times and more errors. At the same time the instructions given before the experiment (or before each block or trial of the experiment) for

Figure 1: A schematic representation of RDK stimuli. In both stimuli the correct answer is 'left'. By varying the proportion which have the coherent motion it is possible to make the decision easy (e.g. 100% coherence) or more difficult (e.g. 50 % coherence).



the participant to be either 'fast' or 'accurate' in making a decision will have different implications for the decision making process. If the participant is fast, more errors are predicted, whereas if the participant is accurate, slow reaction times are predicted. The two features mentioned (i.e. difficulty of the task and speed vs. accuracy instructions) can be traced to changes in key parameters of current computational models of decision making (Ratcliff & McKoon, 2008) and, according to the research question and the aim of the investigation, the researcher can manipulate these and other features of the task to test a vast variety of hypotheses and models related to the decision making process.

The parameters chosen (e.g. speed, density, size) and the algorithm used for the implementation of a RDK (e.g. do the noise dots have constant speed? Do the dots have a limited lifetime? How can dot density be conserved?) significantly affect the behavioural performance of the participant (Pilly & Seitz, 2009). Different RDK algorithms and parameters produce dramatically different performances (Pilly & Seitz, 2009). For example, as it has been shown by Pilly and Seitz (2009), an RDK where the noise is given random direction and

constant speed is psychologically 'easier' (i.e. resulting in higher accuracy scores and lower reaction times) than an identical RDK where the only difference is that the noise is given random direction and random speed. The same rationale (i.e. changing a parameter may result in different performances) holds when other parameters are changed, such as speed, contrast, duration, density or size of the stimulus (Pilly & Seitz, 2009).

This finding highlights the importance of carefully choosing the algorithmic details and the parameters of the RDK for an experiment. Further, researchers should clearly describe the RDK stimuli used in their research in order to promote an easy reproducibility of the results. Here, a particular caution should be exercised in making direct comparisons between studies that involve different parameters and algorithms.

Implementing an RDK from scratch can be very demanding if the researcher does not have strong competencies in computer programming. However, in the past few years some solutions have been proposed for novice programmers. For example, on the web page of Professor Shadlen's Lab at Columbia University, a library of Matlab

codes has been made available (*Variable Coherence Random Dot Motion*; Mckinley, 2007) for creating RDK experiments with Matlab and Psychtoolbox (Brainard, 1997; Kleiner et al., 2007). The great advantage of using this library is that it involves widely-used and widely-tested algorithms for implementing the RDK and with just a little programming effort it enables the creation of a customised RDK experiment for a great number of research questions. Another helpful program for the development of RDK stimuli is PsychoPy (Pierce, 2007), a Python-based software package developed by Professor Jonathan Peirce from Nottingham University. PsychoPy offers a user-friendly graphical user interface (GUI), making it very easy to create an RDK. From the GUI it is possible to select the different parameters of the RDK by choosing their values from a menu. However, there are limits to what can be done using the GUI (e.g. it is not possible to modify the speed of the signal dots within one trial or select different methods for conserving dot density, except the one provided by default). For manipulations that are not allowed by using the GUI, the experimenter needs to modify the Python source code using the PsychPy Coder interface (a text editor) and the supplied Python libraries and dependencies in order to generate the required stimuli. Nevertheless, for both Psychtoolbox and PsychoPy, it is possible to ask for help in the respective official Google Groups and in various online forums (e.g. Stack Overflow).

In summary, I have presented some technical considerations on the RDK and provided some references for a correct

implementation and understanding of this widely-used experimental paradigm. I hope that this short article will be useful for researchers interested in using an RDK task in their research for the first time.

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