ARTICLE IN PRESS

Consciousness and Cognition xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Consciousness and Cognition

journal homepage: www.elsevier.com/locate/concog

Review article

Contingency and similarity in response selection

Wolfgang Prinz

Max Planck Institute for Human Cognitive and Brain Sciences, Stephanstrasse 1a, 04103 Leipzig, Germany

ARTICLE INFO

Keywords:
Choice reaction time tasks
Task representation
Event codes
Task sets
Similarity
Contingency

ABSTRACT

This paper explores issues of task representation in choice reaction time tasks. How is it possible, and what does it take, *to represent such a task* in a way that enables a performer *to do the task* in line with the prescriptions entailed in the instructions? First, a framework for task representation is outlined which combines the implementation of task sets and their use for performance with different kinds of representational operations (pertaining to feature compounds for event codes and code assemblies for task sets, respectively). Then, in a second step, the framework is itself embedded in the bigger picture of the classical debate on the roles of contingency and similarity for the formation of associations. The final conclusion is that both principles are needed and that the operation of similarity at the level of task sets requires and presupposes the operation of contingency at the level of event codes.

1. Choice reaction time tasks

The topic of this paper is quite distant from Bruce Bridgeman's major fields of scientific interest and study. Still, the spirit of the argument aims to come close to Bruce's intellectual style and his way of approaching scientific problems. One of the key features of this style was to combine new experimental observations with old theory: use classical theory to understand novel findings – and, at the same time, use novel findings to elaborate on classical theory. This is exactly what this paper endeavors to do. Its topic is both novel and old. On the one hand, it is "novel" in the sense of addressing an experimental paradigm that has flourished over the past decades – the paradigm of choice reaction time tasks. On the other hand, it is "old" since it addresses theoretical issues that have been debated since the time of Aristotle – namely the roles and the workings of contingency and similarity in mental functioning. Following the spirit of Bruce's intellectual style, the argument will combine novel observations with old ideas, trying to find out how they can inform one another.

Since the time of Helmholtz, Donders, and Wundt choice reaction time tasks have provided an important tool for the study of human performance (Donders and Koster (1868)/1969; Helmholtz, 1867/1924; Wundt, 1902/1904). As research over the past decades has shown, these tasks allow to address the representational underpinnings of basic cognitive operations like stimulus identification, response selection, and response preparation (cf., e.g., Hick, 1952; Sanders, 1998; Smith, 1980; Sternberg, 1969; Welford, 1968, 1980). At the same time, they allow to address basic issues entailed in the formation of task representations as tools for guiding and controlling the interaction of these operations in accord with the demands of the task at hand (cf., e.g., Ach, 1905; Bunge, 2004; Kiesel et al., 2010; Koch, Gade, Schuch, & Philipp, 2010; Logan, van Zandt, Verbruggen, & Wagenmakers, 2014; Prinz, 2015; Schumacher & Hazeltine, 2016; Verbruggen, McLaren, & Chambers, 2014).

In what follows I examine choice reaction time tasks from a task representation perspective: how is it possible to *represent a task* in a way that enables performers to *do the task* according to the prescriptions provided by instructions? When we run experiments, we take it for granted that participants can do what the task requires them to do and we don't care about the miracle that their

E-mail address: prinz@cbs.mpg.de.

https://doi.org/10.1016/j.concog.2018.04.014
Received 11 January 2018; Received in revised form 23 April 2018; Accepted 24 April 2018
1053-8100/

performance must somehow be guided and controlled by representations of the underlying task demands. This is the miracle I am addressing here.

Issues of task representation can be discussed at two levels, implementation and performance. The study of task implementation considers the operations involved in *setting the task.* Analysis at this level addresses the formation of task representations through instructions and practice trials. Instructions for choice tasks must specify three things: the set of possible stimuli, the set of possible responses, and the mapping rules for assigning responses to stimuli. For instance, a minimal choice task may require to map two stimuli (S_1, S_2) onto two responses (R_1, R_2) such that S_1 requires R_1 and S_2 requires R_2 as response. More complex tasks may come with larger sets that may differ in size (so that, for example, eight possible stimuli converge on four responses etc). Whatever the task may be, its implementation requires participants (i) to *understand the instructions* and the task demands entailed in it and (ii) to *form a task representation* that allows them to do the task. Practice trials help to shape this representation and improve its efficiency.

Conversely, the study of task performance considers the operations involved in *doing the task*. Analysis at this level addresses the utilization of representations for task execution. A typical choice reaction task consists of a sequence of trials. On each trial, a stimulus is presented, and participants are required to deliver the appropriate response as fast as they can. Each trial may thus be seen to entail an act of *stimulus-based response selection*. In other words, each trial requires to select one element from the response set, namely the particular response assigned to the current stimulus by the mapping rules specified in the instruction. The time that this act requires forms part of the reaction time, i.e. the total time that elapses between stimulus and response onset.

What does it take to implement a task representation for efficient response selection and what does it take to perform the task according to instructions? To address these questions I take two steps. The first concerns the nature of stimulus- and response representations. What does it take to represent stimuli and responses? What is same and what is different about representations of stimuli and responses? The second addresses the nature of task representations and the assignments entailed in them. What does it take to represent assignments between stimulus- and response representations and how can these assignments be used for action selection?

2. A Framework for response selection

To examine choice tasks, we may adopt two perspectives, external and internal. From an external point of view, we may consider an individual generating certain actions in response to certain stimuli presented to her, thereby following certain rules to which she has committed herself. For instance, she may respond to red vs. green stimulus patches by pressing left vs. right response keys, based on a previously acquired mapping rule that specifies color-to-key mappings.

Conversely, we may adopt an internal point of view. From this perspective, we invoke structural and functional features of a putative cognitive architecture that may account for the observed performance. For instance, as already indicated, we may invoke an architecture harboring stimulus codes, response codes, and linkages between them. Stimulus codes are understood as internal placeholders for external stimuli. They are generated and maintained on the sensory input side of the architecture. Response codes are understood as internal placeholders for external responses. They are generated and maintained on the motor output side. Finally, mappings between stimulus- and response codes are understood as internal placeholders for the stimulus-response assignments specified by task instructions.

2.1. Two principles

So far, the internal description does not provide much more than an internalized version of the external account. In order to make it work, we need to specify what stimulus- and response codes are, and how they are related to each other. Here we encounter two basic principles, separate and common coding (Hommel, Müsseler, Aschersleben, & Prinz, 2001; Prinz, 1984, 1990, 1997).

Separate coding – Separate coding reflects the view that stimuli and responses are entirely different and incommensurate things that have nothing to do with each other. Stimuli are things and events that happen in the outside world, whereas responses are events generated by the body's motor system. Hence, their representations, or codes, must be entirely disjunct and incommensurate. Stimulus codes must carry information about the things and events that have given rise to their formation, and response codes must carry information about the movements to which they give rise. Thus, while stimulus codes specify sensory features like hues or pitches, response codes specify motor features like muscles and forces. If so, there can be no common denominator for them. Still, in order to account for the relationships between stimuli and responses in overt behavior, we need ways of bridging the gap between them. An obvious way to get there is to posit associative linkages that connect one to the other.

Given psychology's historical record of explaining behavior and performance in terms of associations between stimuli and responses, it is perhaps not surprising that separate coding is the mainstream approach in the field (cf., e.g., Broadbent, 1958; Posner, 1978; Sanders, 1998; Sternberg, 1969; Welford, 1968, 1980). Its power is rooted in its universality. Since associations can in principle link anything to anything, they offer themselves as ideal candidates for implementing mapping rules as sets of arbitrary linkages between stimulus- and response codes. Occasionally, the metaphor of *translation* has been used to characterize the logic of the underlying mechanism (e.g., Sternberg, 1969; Welford, 1960, 1968; cf. Prinz, 1990, pp. 169/170). This metaphor suggests that stimuli may specify responses in virtue of linkages between codes from two separate and disjunct coding systems. These systems work like two languages so that something like a dictionary is required to translate one into the other.

Common coding – In one sense, separate coding must thus be true. Still, there are reasons to believe that it doesn't reflect the full truth. A major challenge comes from so-called privileged linkages between perception and action, claiming for a functional role of similarity in the underlying mechanism. The crucial observation here is that stimuli can often more easily be linked to responses