Cognitive Psychology 80 (2015) 1–33

Contents lists available at ScienceDirect

Cognitive Psychology

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

Combination or Differentiation? Two theories of processing order in classification

Andy J. Wills [a,*], Angus B. Inkster [a], Fraser Milton [b]

[a] School of Psychology, Plymouth University, UK
[b] Psychology, University of Exeter, UK

ARTICLE INFO

Article history:
Accepted 26 April 2015
Available online 8 June 2015

Keywords:
Categorization
Category learning
Time pressure
Concurrent load
Holistic
Analytic
Nonanalytic

ABSTRACT

Does cognition begin with an undifferentiated stimulus whole, which can be divided into distinct attributes if time and cognitive resources allow (Differentiation Theory)? Or does it begin with the attributes, which are combined if time and cognitive resources allow (Combination Theory)? Across psychology, use of the terms analytic and non-analytic imply that Differentiation Theory is correct—if cognition begins with the attributes, then synthesis, rather than analysis, is the more appropriate chemical analogy. We re-examined four classic studies of the effects of time pressure, incidental training, and concurrent load on classification and category learning (Kemler Nelson, 1984; Smith & Kemler Nelson, 1984; Smith & Shapiro, 1989; Ward, 1983). These studies are typically interpreted as supporting Differentiation Theory over Combination Theory, while more recent work in classification (Milton et al., 2008, *et seq.*) supports the opposite conclusion. Across seven experiments, replication and re-analysis of the four classic studies revealed that they do not support Differentiation Theory over Combination Theory—two experiments support Combination Theory over Differentiation Theory, and the remainder are compatible with both accounts. We conclude that Combination Theory provides a parsimonious account of both classic and more recent work in this area. The presented data do not require Differentiation Theory, nor a Combination–Differentiation hybrid account.

* Corresponding author.
E-mail address: andy@willslab.co.uk (A.J. Wills).

http://dx.doi.org/10.1016/j.cogpsych.2015.04.002

"Synthesis of any particular letter or figure takes an appreciable time" (Neisser, 1967, p. 103)

1. Introduction

In this article we consider two, approximately opposite, theories of how the psychological processes underlying a classification decision unfold as more time or cognitive resources become available. These two theories might be more accurately described as frameworks, as each captures the basic operating principles of a class of specific theories that are nonidentical. However, this classification of theories is a relatively natural one, with substantial within-category similarities and between-category differences.

The two theories are described here as Combination Theory and Differentiation Theory. The current usage of these terms is novel, but they are intended to capture ideas already present in the literature. Differentiation Theory assumes that classification starts with an undifferentiated whole (a "holistic blob", Lockhead, 1972), which can be broken into its constituent attributes if time and cognitive resources allow. In contrast, Combination Theory assumes classification starts with the attributes, and that information from these attributes can be combined and weighted if time and cognitive resources allow. The widely-used terms "analytic" and "nonanalytic" (Brooks, 1978) presuppose Differentiation Theory—as we will discuss below, they make little sense if Combination Theory is correct.

The question of whether Differentiation Theory or Combination Theory provides the better explanation of classification is controversial. On the one hand, a series of classic studies (Kemler Nelson, 1984; Smith & Kemler Nelson, 1984; Smith & Shapiro, 1989; Ward, 1983) are typically considered to support Differentiation Theory over Combination Theory (e.g. Couchman, Coutinho, & Smith, 2010; Goldstone & Barsalou, 1998). On the other hand, a series of more recent studies employing a slightly different procedure (Milton, Longmore, & Wills, 2008; Milton, Wills, & Hodgson, 2009; Wills, Milton, Longmore, Hester, & Robinson, 2013b), largely support the opposite conclusion. The current investigation offers a reconciliation of these apparently incompatible studies. The reconciliation we offer is that Combination Theory provides a parsimonious account of both sets of studies. Differentiation Theory is directly disconfirmed in two cases.

1.1. Combination Theory

In Combination Theory, the input to the classification system is in the form of a set of distinct attributes (dimensions or features). Classification on the basis of multiple attributes involves the collection of information across those attributes, which takes time. Classification on the basis of multiple attributes sometimes involves weighting those attributes differently. This also takes time, possibly more time than employing an unweighted combination.

The intellectual roots of Combination Theory can be traced back at least as far as the fuzzy logical model of perception (Oden & Massaro, 1978; Thompson & Massaro, 1989) and feature-integration theory (Treisman & Gelade, 1980). One formal instantiation of Combination Theory within categorization research is Lamberts's extension to the GCM (Generalized Context Model; Nosofsky, 1984), the EGCM (Extended Generalized Context Model; Lamberts, 1995). EGCM is a stochastic sampling model; each attribute is assigned a hazard function such that the probability of that attribute having been sampled by time zero is zero, increasing thereafter. Thus, the more time available to observe the stimulus, the more dimensions, on average, will be available on which to make a response. Another, less formal, example of Combination Theory is Dimensional Summation theory (Milton & Wills, 2004). Dimensional Summation theory assumes a serial, limited-capacity, rule-like process. Stimulus dimensions are intentionally, sequentially, queried until sufficient information is available to apply the currently selected categorization rule. Taken together, EGCM and Dimensional Summation theory provide two illustrations that Combination Theory can, at the level of detailed process, be implemented in a number of architecturally distinct ways.