THE PSYCHOPHYSICS OF LEARNING

Implications for Learning Systems Design and Configuration

JOHN N. MOYE

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The Psychophysics of Learning: Implications for Learning Systems Design and Configuration

BY

JOHN N. MOYE

Performance Learning Technologies, USA

emerald PUBLISHING

United Kingdom – North America – Japan – India – Malaysia – China

Emerald Publishing Limited
Howard House, Wagon Lane, Bingley BD16 1WA, UK

First edition 2021

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Contact: permissions@emeraldinsight.com

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

ISBN: 978-1-80117-114-4 (Print)
ISBN: 978-1-80117-113-7 (Online)
ISBN: 978-1-80117-115-1 (Epub)

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Contents

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List of Figures and Tables

Abstract

Learning is an inherently neurological process that involves receiving, processing, and making sense of external information. Neurologically, these are the processes of sensation, perception, and cognition and the psychophysics of these phenomena provide insight into the methods and techniques the brain uses to engage with, process, and internalize the meaning of new information to each individual.

This work collects and codifies the psychophysical research for each sense. These research findings are used to create design frameworks for the learning engagement, learning experience, and learning environment, which creates a psychophysical model of learning that simulates the natural processes the brain uses to learn from external stimuli. These design models are translated into practical approaches to curriculum, instruction, and experience design strategies, which promote and enhance learning outcomes for all learners. As a result, learner access to information, consonance with learning processes, and internalization of the learning are aligned with the information processes strategies of the brain.

Keywords: Learning; psychophysics; learning engagement; learning experience; learning environment; learning access; information processing; curriculum design; instructional design; learning ecology; collective learning; implicate order; learning alignment; social integration; diverse learning processes; sensation; perception; cognition; interconnectedness; interaction

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Chapter 1

Purpose and Intent

Educators regularly design and implement learning systems. A learning system involves the input of information, the processes that transform information into useful knowledge, and the procedures the brain uses to internalize knowledge into the individual's learning ecology. Regardless of the medium used to deliver and process information for learning, the actual learning takes place inside each learner's brain. Designing effective learning for other humans requires the designer to know and understand the neurological processes and procedures all humans employ to learn (Collins, 2019).

These neurological processes are the systematic study of sensation, perception, and cognition, which are the electrical processes the brain uses to receive, transform, and make sense of external information. The sciences of sensation, perception, and cognition provide conceptual frameworks that learning designers can use to configure learning objects, processes, and environments for all learners. The transduction of external information into internal learning is the science of psychophysics.

The purpose of this work is to synthesize the extensive findings of psychophysical research identifying the factors to which the perceptual system attends to make sense of external stimuli (Ashby, 1992; Townsend et al., 1992; Tsushima & Watanabe, 2009) into models and frameworks that can design effective and efficient learning systems. This work assumes that the psychophysics of sensation, perception, and sensory cognition mirror the psychophysics of active learning (Connolly, 2019; Jensen, 2008). Therefore, the psychophysics of sensation, perception, and cognition provide practical and useful frameworks to design an effective learning system, which engineers learning. In the psychophysical approach, a learning system contains the dimensions of learning engagement, learning experience, and learning environment, which directly correlate to the sensation, perception, and cognition processes of the neurological system. In a learning system, the transduction of information from a physical stimulus into neurological data is the psychophysics of learning.

Limitations

This work conducts a high-level review of the psychophysics of the perception of hearing, vision, taste, smell, and touch to determine those factors to which the brain attends to learn. Therefore, this work is not an in-depth exploration of the

The Psychophysics of Learning, 1–7

Published under exclusive licence by Emerald Publishing Limited
doi:10.1108/978-1-80117-113-720211001

neurosciences, anatomy and physiology, or other sciences that measure and assess the electrical processes of the brain. It is limited to synthesizing the conclusions of those sciences into cogent learning system design frameworks to achieve the goal of creating "ideal" learning systems (Diamond, 1998) for all learners.

The field of psychophysics is an extensive and comprehensive collection of primary research, which systematically examines the sensory processes of sensation, perception, and cognition. These neurological processes equate to the processes the brain uses to learn, which this work describes as the psychophysics of learning. The most applicable (and accessible) references are reported for each concept extracted from the psychophysical research and emulated in learning to process information into deep learning. However, these works are often highly technical and provide a level of detail that is unnecessary and distracting for the current purpose.

Need

The Reference List in this work demonstrates the prior and current interest of the learning professions in the order a psychophysical perspective brings to the processes of learning system design (Hamilton, 2013). Many references provide direct evidence of the professional education community's interest in the neurological processes of learning to reveal strategies to improve curriculum, instruction, and learning.

Neuroscientists have warned educators about the use of neuroscientific research to "defend" their educational decisions (Bowers, 2016; Bruer, 1997; Hook & Farah, 2013; Jaeggi & Shah, 2018; Mayer, 2017; Weisberg et al., 2007). Their concern is that the lack of neuroscientific expertise could lead to misinterpretation or misapplication of primary neurological research. This concern is valid and justified for any research used by other disciplines.

Additionally, several authors have indicated the need for works that apply psychophysics' findings to practical situations (Al Dahhan et al., 2016; Glick, 2011; Kingdom & Prins, 2016; Ljunggren & Dornic, 1989; Lu & Dosher, 2014; Rhodes et al., 2014; Treisman, 1991). Psychophysical approaches increasingly appear in published educational research (Collins, 2019; Esteban-Guitart & Gee, 2020; Howard-Jones et al., 2016; Kricos et al., 1996; Lubashevsky, 2019; Osgood-Campbell, 2015; Tsushima & Watanabe, 2009; Zirk-Sadowski, 2014). The findings of psychophysical research provide plausible strategies and tactics, which can be adapted, applied, and assessed to determine their effectiveness in learning (Kim & Cameron, 2016; Moye, 2019a).

Psychophysics reflects the conclusions of neuroscientific research and neuroscientists as defined and communicated by neuroscientists. These conclusions are applied, tested, and confirmed at the boundary between the neurological processes and the physical result. In this work, neuroscience is mentioned only when necessary to support or explain the psychophysics of a process and only when it is necessary to understand the influence of that conclusion on learning systems design.

Measurement

A well-discussed main limitation to the field of psychophysics occurs in the measurement strategies used to study perceptual and cognitive phenomena (Carterette, 1974; Colonius & Dzhafarov, 2006; Holman & Marley, 1974). Most texts on the subject of psychophysics include lengthy explanations of the measurement and assessment strategies used to find meaning in the research data and the limitations of those strategies.

Psychophysics is an applied science, as is learning. The field of psychophysics provides a collection of research and statistical models for practical research models and assessments, such as institutional research and phenomenological assessment (Berglund, 2012; Gyr & Pribram, 1994; Holman & Marley, 1974; Indow, 1974; Jones, 1974; Lawless, 2013). The value and contribution of this discipline to the field of higher education are profound, and the lack of certainty surrounding its findings does not preclude its use to develop plausible models, which can be applied to real-world situations and measured in that environment. Learning science is based on observation. The psychophysics of sensation, perception, and cognition provides plausible evidence for the configuration of curriculum and assessments (Moye, 2019a, b; Reynolds, 2005).

One of the most critical conclusions from the field of psychophysics is that learning is multilinear and phenomenological (Ashby, 1992; Gescheider et al., 2009; Tsushima & Watanabe, 2009). As such, linear strategies cannot achieve or measure it. At the very least, it is multidimensional and dynamic (interactive), which requires the use of multidimensional scaling strategies (Carroll & Wish, 1974), and many laboratory researchers are not comfortable with these strategies (Lawless, 2013). The discomfort with the measurement strategies has led many researchers to dismiss the research findings and conclusions of the field as non-scientific (Savage, 2021). Therefore, in this work, the word "systematic" will describe the research designs that provide the data and information upon which the conclusions in this work are based (Carterette, 1974; Carterette & Friedman, 1978; Colonius & Dzhafarov, 2006).

The brain of either human or animal subjects cannot be dissected and observed responding to sensory stimuli in real-time. Even with neuroimaging methods, it is necessary to use indirect measures to understand the brain's behavior and attention (Phélip et al., 2016; Richardson et al., 1992).

In psychophysics, the data collection takes place at the sensory level, where it cannot be directly measured and is encoded and reported in models to the perceptual level. There appears to be no data transformation at the sensory level, just the reporting of the architecture (content and structure) of the characteristics of the stimulus. Sensory information is detected in the sensation process and communicated to the perceptual system, where the brain responds to those characteristics to discriminate the meaning of the external stimulus. Cognition filters the perception through prior learning and behaviors of the individual who has experienced, discriminated, and internalized them as learning within the brain. This process follows a basic systems model in which data are input, transformed, and output as internalized cognition.

As a result of these constraints, psychophysics contains very sophisticated measurement and assessment techniques to collect research data, which also provide excellent models to consider in the study of many educational phenomena (Berglund, 2012; Carroll & Wish, 1974; Gyr & Pribram, 1994).

Related Disciplines

This effort analyzes and categorizes the brain's factors to make sense of (learn) from the external environment. While each sensory system responds to different types of physical energy, there are commonalities (invariances) across the five senses in the neurological processes used to sense (detect), perceive (discriminate), and make sense of events, artifacts, and interactions with these stimuli. These commonalities delineate a model for the configuration of instructional systems, which emulates the psychophysics of perception and cognition to build a learning system. It attempts to allow the brain to identify the characteristics of experience to which it attends, to input a stimulus accurately, process that perception signal to make sense of it, and use that information to generate cognition, in other words, to learn from a physical stimulus.

The field of research is different from several closely related disciplines, often conflated with psychophysics. This work differentiates these fields as follows.

Neuroscience studies the response of cells within the brain to an external physical stimulus (Vaughan-Graham et al., 2019; Xiaolong et al., 2015). Neuroscience focuses on the electrical activity within the brain and at the cellular level. While its findings are often related to higher-level functions in human experience, neuroscience itself is limited in its ability to related directly to human experience without factoring in the higher level sensemaking, which takes place beyond the neuronal level (Haller, 2014; Müller et al., 2011).

Neurophysiology studies the structure and components of the nervous systems and how they transmit the information received from the external environment to the cerebral cortex of the brain (Carpenter & Reddi, 2012). It examines the brain's physical response patterns to a stimulus (Perruchoud et al., 2018) to develop or repair physical ailments and diseases (Schalow & e-Libro Corporation, 2013).

Neuropsychology, according to Westwood & Goodale (2011), is a subdivision of the field of psychology, which is equivalent to psychophysics.

Signal detection is the systematic study of sensory systems' response to a physical stimulus and how those systems encode the information into neurological (electrical) representations (Soto et al., 2018; Walsh, 2017). In the sensory systems, the information is compiled into the neurological models, which summarize and categorize the physical information (Mariani et al., 2019).

Information processing is a multilinear process the sensory conducts with the encoded information to summarize and compile that information into groups (channels) and patterns (clusters) of response (Gescheider et al., 2009; Yard et al., 2005). The characteristics (alignment, channels) and interdependencies (models) within the data define this modeling process (Lincoln, 2019).

Perception examines the processes the brain uses to evaluate the data models and create a psychological perception of that model (Ashby, 1992). Perception begins the process of creating a subjective understanding of that stimulus (cognition) through psychological processes that discriminate the objective data models for meaning (Müller et al., 2011).

Psychophysics studies the details of translating the external signal into a perception of that signal (Colonius, & Dzhafarov, 2006; Gescheider et al., 2009; Jacobs & Grainger, 1998; Stevens, 1967; Townsend et al., 1992). Psychophysics examines the characteristics of a stimulus to which the brain attends to perceive meaning from the stimulus (Ashby, 1992; Houpt & Blaha, 2016a, b; Kalloniatis & Luu, 1995a, b).

Cognition studies how the brain creates knowledge (interprets) from the perception and is evaluated with prior learning and knowledge (Houpt & Blaha 2016a, b; Mather 2009; Townsend et al., 1992).

Systems Models

In this work, the goal is to identify the attributes of a psychophysical learning system. From this approach emerges the conclusion that these processes organize as a system of systems. In anticipation of these discussions, Table 1.1 depicts an

Table 1.1. The Systems of Psychophysical Learning.

	Input	**Transformation**	**Output**
Sensory System	Sensation	Perception	Cognition
Focus	External stimulus	Sensory signal	Perception
Function	Resonance	Data reduction	Ecological learning
Purpose	Record and encode stimulus	Reduce to critical model	Create new learning
Output	Neuronal model	Perceptual model	Cognition
Process	Aggregation of sensory data	Model perceptual data	Internalize perceptions
Structure	Linear	Multilinear	Phenomenological
Learning System	Engagement	Experience	Environment
Information Processing	Receive	Integrate	Internalize
Thinking	Dualistic	Multiplistic	Relativistic/ Complex
Learning	Knowledge	Analysis/ Comprehension	Application/ Synthesis

analysis of the sensory systems' processes and the corresponding learning system to differentiate and conceptualize the systematic nature of psychophysical and learning processes.

Nested Systems

Several systems are nested within each other and interacting to produce the universal outcome. The following systems contribute to the ultimate goal of learning.

Sensory Systems

The sensory system, located in the sense organs and central nervous system, responds to physical energy and transduces that physical energy into electrical nerve impulse data. These data are sorted, filtered, and grouped into channels of information, which reveal the constructs or factors that comprise the stimulus. Within each channel, the patterns that emerge within the data delineate models of the information transmitted to the brain through the central nervous system.

Perceptual Systems

The perceptual systems, located in the neocortex on the surface of the brain, receives the modeled information from the sensory system, discriminates that information for meaning, and outputs that information to the higher levels of the brain.

Sensemaking and Cognition

The overarching system under discussion is a process of "sensemaking" to discover plausible meaning and achieve cognition. Cognition results from the processing of perceptions, which compares and integrates the perception into the prior experience and knowledge of the individual (Lawless, 2013). This work labels the process as sensemaking, and the output of that process is cognition. From a learning perspective, cognition is also an internalization process, which begins with initial cognition and continues after the cognition process concludes. This form of cognition supports the concept of "lifelong learning," which is an outcome of many educational missions, visions, and values. Lifelong learning is a quantum process, which internalizes learning into the information processing strategies valued by the individual (Conner, 1992; Moye, 2019b; Torosyan, 1999). For this discussion, the sensemaking process collects information, discriminates the content and structure of the information, and constructs an outcome or cognition of the input.

Cognition relates to the development of knowledge and understanding (the ability to apply to multiple situations) by evaluating sensory and perceptual information. There are other authentic uses of this term that study the neuroscience of brain activity during cognitive activities. In this work, the term describes the outcome of the processing (sensemaking) of sensory and perceptual information obtained from an external stimulus.

In the sensemaking system, the perception of an external stimulus is the input to the cognition process, which internalizes that perception by comparing the perceptions with prior learning of the individual into a higher-order learning than in the sensation and perception processes (Herrmann et al., 2012; Raju, 2019). This learning is quantum learning in humans (Afacan & Gürel, 2019; Altın & Saracaloğlu, 2019; Le Tellier, 2006) and machines (Arunachalam et al., 2019; Beer et al., 2019; Liu et al., 2019).

Quantum learning emerges from the evaluation of perceptions for their relationship to prior learning of the individual and synthesizes the new information with the prior learning to blend into the totality of their cognitive experiences, described in this work as the individual's learning ecology (Aedo et al., 2019; Bloom, 1999; Borden, 2017; Gaete et al., 2020; Reynolds, 2005; Winter, 2003; Zhang, 2019). Sensory inputs and perceptual processes are parts of a learning system and not a complete learning process in a quantum model of learning (de Almeida & Santos, 2012; Brown et al., 2016; Imai, 1992; Ljunggren & Dornic, 1989; Marcum, 2006a, b, c; Mather, 2016).

In a learning system, new information is continually synthesized with prior information to advance individual cognition. While cognition is the outcome, it is never complete in the life of a human being, and the learning systems of the brain suggest this is the case. Effective instructional systems can make the same assumptions and designed to create authentic "lifelong learning" (Bloom, 1999; Gaete et al., 2020; Reynolds, 2005; Torosyan, 1999).

The systematic structure of these processes will be discussed further in the coming chapters.

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