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COMMENTARY

A Continuum of Learning and Memory Research

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History has revealed time and time again that science is moved forward by revolutions that pit one point of view, theory, or methodology, against an opposing view. During calmer times, however, we as researchers are left to our own devices and settle into our work with little thought to the world around us. The field of learning and memory has been privy to many such revolutions in the past but has yet to form a cohesive, modern message. Grau and Joynes suggest that our strong ties to the past are to blame for a lack of progression in the field. We agree and add that the focus of the field on two extreme ends of a continuum has also held us back; suggesting that research that goes on in the middle of the continuum may be the key to leading the field out of its rut.

Grau and Joynes (2005) posit that there are two core assumptions that maintain and nourish research in the field of learning and memory. The first assumption, which is not problematic to the authors (nor to us), is that learning is essential. The second assumption, however, is where Grau and Joynes assert that the field has been led down a "problematic path" (p. 2)—that the interpretation of the assumption of generality in learning has led the field astray. Specifically, the study of phenomena with traditional methodologies that manipulate relationships between stimuli and responses, such as Pavlovian, operant, or instrumental conditioning paradigms, has resulted in the methodologies and procedures themselves taking precedence over the phenomena being studied.

Grau and Joynes have pointed out an important problem in the field of learning and memory. The way in which many in the field of learning cling to traditions established long ago is troublesome not only for the research we perform and the data we obtain but also for the dissemination of the field, and our findings, to others. This problem is especially evident in the university classroom. Few would argue the fact that when we construct a curriculum for a course on learning and memory, we perpetuate the very problem in the field that Grau and Joynes identify. Not yet has a comprehensive text been written that has even come close to tearing down "the traditional house" (p. 2) thereby reinforcing a segregation of theory with no attempt at synthesis.

Although it is quite evident that the way in which we teach learning to students is in desperate need of "modernization" it is also important for a synthesis across research programs. Many of us, however, do strive to achieve this goal. In fact, the incursion of the problem of generality in research, as emphasized by Grau and Joynes, arises from a blurring of two extreme ends of a continuum. To this extent, the authors' criticism of using particular methodologies—setting up shop in a single room (p. 2)—although important, may be a bit overstated.

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Researchers who study behavioral and biological underpinnings of learning and memory, like researchers involved in many scientific disciplines, have research interests that can be placed on a continuum. At one end of the continuum there are researchers interested in describing and uncovering the laws of behavior based primarily on a history of traditional learning theory and animal behavior. Not surprisingly, these researchers use traditional methodologies to achieve that goal. At the other end of the continuum, researchers may have little concern for learning in and of itself, instead being interested in understanding the laws of neurobiology that are associated with the behavior. These researchers also use traditional methodologies because the resultant changes in behavior that are known from previous work provide them with a means to assess neural and molecular substrates of learning. The point on the continuum that one decides to "set up shop", therefore, depends on the specific interests, goals and training of the individual researcher.

The dichotomy that establishes the endpoints of such a continuum is not unique to the study of learning and memory. It has spurred on many important scientific revolutions; evolution, developmental biology, and psychology, and of course in learning as well—God vs. natural selection, nature vs. nurture, behaviorism vs. cognitive psychology. While these extreme positions frequently act to garner our attention and make us think more deeply about our work, the majority of us do not see the world in quite so black and white terms. It may be argued that much of the work that moves us forward and fills in the gaps arises from the gray areas, the middle of the continuum. A good example of work at the middle of the continuum is the use of fear conditioning procedures to study the role of structures like the amygdala and hippocampus in emotional learning (e.g., Fanselow, 2001; Lamprecht and LeDoux, 2004). Many laboratories have adopted variations of fear conditioning procedures to study how brain systems interact and encode this form of learning in a number of difference species (including humans). Much of this work has advanced our understanding of acquired fear behaviors while at the same time advancing our understanding of the neurobiological underpinnings of the behavioral change.

It is true, as Grau and Joynes point out, that the majority of researchers utilize a rather small set of traditional methodologies (i.e., Pavlovian, operant, or instrumental conditioning). Obviously at one end of the continuum the interest is in the methodology itself, while at the other end the methodology serves as a tool for looking at other events (i.e., neural activity, protein synthesis, receptor populations). The use of traditional paradigms/methodologies as research tools, however, is not necessarily the result of "seeking a safe course" as Grau and Joynes suggest (p. 3). Many of us utilize traditional learning paradigms because they allow us to control a larger number of experimental variables so that underlying neural function can be assessed. Our own work in studying how structures like the cerebellum and hippocampus are involved in classical eyeblink conditioning provides an example of this use of a traditional paradigm (see Steinmetz, 2000, for review). Due to the elegant and comprehensive behavioral work of Isadore Gormezano, Allan Wagner, James Kehoe, Berny Schreurs, and others, we know what to expect behaviorally when manipulations such as those involving interstimulus intervals, intertrial intervals, and stimulus intensity are performed. Being able to predict what happens behaviorally when variations of this basic, traditional learning procedure

are performed has greatly aided our ability to elucidate neural processes associated with the learning. In other words, it is not so much that we are suspicious of other paradigms, rather, we use what works optimally and predictably for elucidating mechanisms underlying the phenomena we are studying.

The importance of mechanism is well-established by Grau and Joynes, and the authors suggest that mechanism should be the focus of the field as opposed to methodology. We too appreciate the importance of mechanism(s) and it is what drives our research program. Mechanism, however, is not immune from the problems suffered by methodology**.** Mechanism may vary due to methodology at a behavioral level (e.g., operant conditioning vs. instrumental conditioning) or at a neural level (e.g., what and how brain structures are engaged during learning). An example from the classical eyeblink conditioning literature may serve to illustrate this point. From a behavioral standpoint, evidence for the acquisition of the classically conditioned eyeblink response is the appearance of anticipatory conditioned responses (CRs), which we can call the behavioral mechanism. A number of studies have shown that a small lesions placed in the interpositus nucleus of the cerebellum can abolish this type of learning (e.g., Steinmetz, Logue, & Steinmetz, 1992). From these (and other) data it has been established that the cerebellum is critically involved in the acquisition and performance of the classically conditioned eyeblink response (see Steinmetz, 2000, for review). This is an example of a neural mechanism. Several years ago, Kelly, Zou, and Bloedel (1990) reported the appearance of eyeblink CRs in rabbits that had cerebellum and cerebral cortex removed (i.e., essentially a brainstem preparation). Do these data show that the cerebellum is not critical for classical eyeblink conditioning? Probably not. These data more likely demonstrate the uncovering of plasticity processes in the brain stem after cerebral cortical input is eliminated, a second neural mechanism that is capable of supporting the appearance of the behavioral mechanism (the conditioned eyeblink). Importantly, this second neural mechanism cannot independently support conditioned responding in the intact preparation where the cerebral cortical input is present. This example illustrates the point that a given behavioral mechanism may be accounted for by a number of different neural mechanisms that play different roles in producing the behavior depending on the components of the nervous system that are available to the organism. Indeed, many neural mechanisms may in fact be overlooked or under-appreciated because of traditional mechanisms that hold sway in the field (i.e., cortical inhibition, LTP, LTD, PKC, etc.). Again we see that the problem of generality of neural mechanisms to be just as potentially troublesome here as it is when traditional learning methodologies or phenomena are compared (e.g. Is latent inhibition mechanistically, both behaviorally and neurally, the same during appetitive and aversive forms of instrumental learning?).

Grau and Joynes should be applauded for their efforts to regroup and revitalize the field of learning and memory. Their caution of leaning too heavily on old theories, both in our research and in our classrooms, is well warranted. Their position of neural functionalism, focusing on motivational and operational behaviors and the underlying neural mechanisms, is sound. In fact, many of us would purport to already be converts or followers. In the end, our goal as researchers in the field (regardless of our location on the continuum) should encompass an understanding of learning that can explain phenomena across methodologies, in different species,

and across development. When we get to this point maybe we will have learned something.

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