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Promoting Translational Research Among Movement Science, Occupational Science, and Occupational Therapy

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Abstract

Integration of research in the fields of neural control of movement and biomechanics (collectively referred to as movement science) with the field of human occupation directly benefits both areas of study. Specifically, incorporating many of the quantitative scientific methods and analyses employed in movement science can help accelerate the development of rehabilitation-relevant research in occupational therapy (OT) and occupational science (OS). Reciprocally, OT and OS, which focus on the performance of everyday activities (occupations) to promote health and well-being, provide theoretical frameworks to guide research on the performance of actions in the context of social, psychological, and environmental factors. Given both fields' mutual interest in the study of movement as it relates to health and disease, the authors posit that combining OS and OT theories and principles with the theories and methods in movement science may lead to new, impactful, and clinically relevant knowledge. The first step is to ensure that individuals with OS or OT backgrounds are academically prepared to pursue advanced study in movement science. In this article, the authors propose 2 strategies to address this need.

Keywords

occupational therapy; occupational science; movement science; neural control of movement; neuroscience

The integration of movement science with the science of human occupation provides a promising approach to accelerate the development of translational research in neurorehabilitation. Translational research is characterized by the conversion of scientific knowledge into clinical applications, and can be described as a sequential process. The first

stage is composed of preclinical basic science studies that serve as the foundation for the development of small scale, proof-of-concept, intervention studies in clinical populations. These small scale studies form the foundation for the final stage, involving large-scale intervention studies (Cheerin et al., 2009). We suggest that this translation can be enhanced in rehabilitation by the (a) integration of occupational therapists into basic science research that informs the first stage of the translational pipeline and (b) integration of movement science methodologies at the final stage of the pipeline in order to improve the assessment of responses to intervention in clinical populations.

Occupational science (OS) currently serves as the major science foundation for translational research in occupational therapy (OT). OS is an interdisciplinary field that is focused on understanding the basis of human occupation, defined by the activities that make up daily living. More specifically, the term *occupation* can be defined as the broad range of activities that are performed as a natural part of life. Typically, these activities are classified into one or more of the following domains: physical (e.g., walking, gardening, mountain climbing), productive or work related (e.g., typing, driving, welding), social (e.g., dining with friends, attending a concert), religious (e.g., going to church, praying), and leisure (e.g., painting, attending a sports event; Clark et al., 2015). Historically, OS has focused heavily on social and behavioral sciences, with little emphasis on the movement science and neurobiological foundations of human occupation. This has hindered progress in OS by isolating it from theoretical and methodological developments in relevant basic science and engineering disciplines.

OS and OT define a translational spectrum in which research in OS is intended to inform the development of evidence-based practices in OT. In contrast, OT is a health care profession dedicated to employing meaningful occupations (activities of living) therapeutically or preventively (Clark et al., 2015; Gray, 1998; Zemke & Clark, 1996). Despite these distinctions, the field of occupation as a whole has recognized the need for the translation of knowledge between OS and OT and neuroscience since its founding nearly a century ago (Meyer, 1921). In fact, this issue has been a consistent consideration throughout the development of both OT and OS. However, realization of this objective has been modest at best. To realize the full potential of this translational spectrum will require that a critical mass of occupational therapists and occupational scientists receive rigorous training in neuroscience and biomechanics.

Although the integration of movement science into OS and OT is not new, progress in furthering this aim has been slow. One barrier to generating translational research is the fact that graduate programs in neural control of movement or biomechanics require students to complete previous coursework in physics, chemistry, and calculus. These courses, however, are neither prerequisites for nor a standard component of accredited OT professional educational programs. This fact precludes many would be OT and OS researchers from pursuing higher studies in movement science and serves to isolate OT and OS further from capitalizing on developments in relevant basic sciences and engineering. Were more researchers equipped with an interdisciplinary background, then the probability of innovative, clinically relevant findings in movement science would likely result. This is a

two-way street, with potential to benefits to movement science by increasing its clinical relevance and impact.

In the field of movement science, a great deal of research is being conducted to understand processes underlying occupational tasks at the biophysical, neural, and cognitive levels of analysis (e.g., reaching toward targets and objects, throwing and catching a ball). A sizeable presence of movement scientists with OS or OT backgrounds is likely to produce novel and interesting insights into the cognitive-motor spectrum underlying human occupation. A movement scientist with a background in OT or OS could facilitate the development of more ecologically valid research paradigms that better capture meaningful human activities and enhance generalization of results to settings beyond the lab. Imagine, for example, if broadly trained movement scientists one day discovered that the degree to which an activity is experienced as meaningful significantly impacts crucial parameters of motor performance of the affected limb in stroke. Such researchers might determine that there is no relationship between precisely measured ball catching ability in a carefully controlled laboratory paradigm and on the actual playing field. Moreover, what if performance is significantly better during a real game as measured by data gathered on several wearable monitors? What new scientific questions would emerge from these findings? And finally, what if we found that direct current brain stimulation over a particular region had no effect on a laboratory-based task performance, but that stimulation over the same region improved participant's execution of similar tasks in the more complex and dynamic home environment? The point is that research born of a marriage between OS and movement science could ultimately lead to much improved and innovative neurorehabilitation approaches. Producing a cadre of scientists prepared to address these questions is a necessary prerequisite. Although the task will not be easy, simple strategies that we outline at the end of this paper can jump-start the effort.

OCCUPATIONAL THERAPY AND OCCUPATIONAL SCIENCE

OT is often considered difficult to define because it (a) portrays occupation differently from colloquial usage (see Introduction), (b) applies to an extremely wide-range of populations, and (c) uses diverse and sometimes complex intervention approaches. One simple definition of OT, however, that coincides with the aims of neurorehabilitation is a health care profession whose primary concern is the development or recovery of engagement in everyday occupations, among which are included mundane tasks such as hygiene and grooming activities, donning and doffing clothing, and preparing and eating meals, as well as more complex activities such as those enacted in the context of work, play, or leisure.

When the academic discipline of OS began in 1989, the field's founder Elizabeth J. Yerxa et al. (1990) defined it as the study of human occupation. In addition, they determined that the research generated from OS would focus not only on biological substrates, but also on the psychological, social, and environmental factors that influence engagement in everyday activity. Expanding on this original conceptualization, in 1996 Zemke and Clark described OS as a human science focused on the study of occupation in all contexts, including therapeutic. This definition implied that both a study on how environmental factors impact participation in daily activity and a randomized controlled trial of the efficacy of a particular

activity-based intervention in producing rehabilitation-relevant outcomes fall within the conceptual boundaries of OS. As it has evolved over the past 27 years, OS has increased our understanding of the complexity of factors that influence occupation and its impact on health and well-being and created an evidentiary base to validate OT practice (Clark et al., 2012; Clark et al., 2006; Clark et al., 1997; Gitlin et al., 2008; Jackson et al., 2010).

Given the holistic and biosocial orientation of OT and OS, the field has overlooked the acquisition of knowledge in fields such as chemistry, physics, or calculus for advanced studies in anatomy, physiology, and the social sciences. The *Journal of Occupational Science* demonstrates this trend when describing the academic discipline as follows: “studies of populations, communities, groups and individuals, as well as explorations of people’s development as occupational beings, patterns of occupation, societal structuring of occupation, and differential access to occupation.” This scope includes “humanist, indigenous, population, transactional evolutionary, biological, ecological, historical, socio-political, philosophical, and biographical” perspectives of occupation. Because OS is viewed, in large part, as forming the scientific basis of OT, training in OT subsequently and substantially focuses on biology, sociology, anthropology, and certain subdisciplines of psychology. The prerequisite courses for entry into the top three professional graduate degree programs in the field—Boston University, Washington University, and the University of Southern California (US News and World Report, 2016)—include one or more anatomy and physiology courses, statistics, and select courses in the social sciences (e.g., sociology, psychology). Notably, none of these programs currently requires foundational coursework in calculus, physics, or chemistry.

MOVEMENT SCIENCE

Human occupation requires the integration of cognitive processes with sensorimotor control. In turn, this neural substrate relies on input from the visual or other sensory systems in order to plan, coordinate, execute, and correct movements such as reaching toward and manipulating objects (e.g., tools, utensils, clothing) with which we interact daily. The cognitive, perceptuomotor, and musculoskeletal processes that underlie such tasks are the focus of research in movement science, particularly the neural control of movement and biomechanics. A subspecialty of neurobiology, the study of the neural control of movement, examines the interaction of the nervous system, body, and its environment in order to plan and execute movements. Biomechanics examines the physical factors that afford both constraints and advantages to the musculoskeletal system during environmental interactions. For the most part, movements addressed by both fields include the elemental tasks that form the basis of human occupation; however, to control for potentially confounding variables, these tasks are often studied under rigidly controlled and highly artificial conditions.

Furthermore, neural control of movement integrates information from neurobiology, computational sciences, neuroscience, cognitive psychology, physiology, biomechanics, and engineering control theory. Despite its moniker, research in this area has emphasized the critical importance of sensory information in carrying out even the simplest aspects of voluntary movement. A major limitation in translating research on the neural control of movement into practice is the field’s difficulty with investigating task performance carried

out everyday, and motivating meaningful real-world settings where people naturally live and learn. Therefore, comprehensive research programs, through which laboratory-based findings begin to shape the aims and designs of studies conducted in natural environments and vice versa, are necessary. Through this effort the possibility of more efficacious interventions that may be of practical value in the lives of people with disabilities may increase.

MOVEMENT SCIENCE, OCCUPATIONAL SCIENCE, OCCUPATIONAL THERAPY, AND THE INTERNATIONAL CLASSIFICATION OF FUNCTION, DISABILITY, AND HEALTH

The International Classification of Function, Disability, and Health (ICF) model provided by the World Health Organization illustrates how knowledge gained in movement science might pertain to the conceptual boundaries of OS and OT (see Figure 1). Activity is at the center of the model, which describes functioning at three levels: the body, the person, and society. The ICF model depicts how disability and functional limitations result from problems in activity, defined as the execution of a task or action by an individual. Participation refers to involvement in a life situation. A disruption at the person level should be interpreted as an activity limitation, but at the societal level as a participation restriction. According to this model, neural control of movement and biomechanics research address body function and structures (the left end of the spectrum), OS and OT address participation (the right end of the spectrum), while the three overlap at the level of activity (see gray boxes in Figure 1). In fact, this model also has a counterpart in translational research models that communicate between basic scientific questions on one end (T0 level) and outcomes research with a population health impact at the other end (T4 level; Khoury et al., 2007). Regardless of how one views the spectrum, it is evident that movement science addresses the impact of body functions and structures on activities, while OS and OT primarily focus on the relationships between activity and participation in the research or clinical care context.

INTEGRATION OF MOVEMENT SCIENCE WITH OCCUPATIONAL SCIENCE AND OCCUPATIONAL THERAPY

We believe that a great deal can be gained by integrating knowledge generated across the fields of movement science and OS. Many, but not all, occupational scientists and therapists conduct research or practice in the area of neurorehabilitation. These individuals share with movement scientists a longstanding interest in the neural and biomechanical influences on action, and in understanding how task and occupational performance are affected by disorders in the musculoskeletal or nervous systems. Occupational scientists and therapists also frequently rely on measurements of parameters that reflect the integrity of these same systems to document significant beneficial effects of an intervention or clinically meaningful change. It is not surprising, therefore, that some of the early rehabilitation techniques employed clinically by occupational therapists in the 1960s and 1970s were based on principles of nervous system functioning purported in the neuroscience of the time (Bobath, 1978, 1990, 1991; Voss, 1959, 1967; Voss, Ionta, & Myers, 1985).

A limited amount of recent research in OT has incorporated movement science in order to understand occupational performance. For example, the work of Trombly et al. (Lin, Wu, & Trombly, 1998; Trombly & Wu, 1999; Wu, Trombly, Lin, & Tickle-Degnen, 1998, 2000) employed movement tracking and kinematic analysis of reaching to explore whether the quality of one's reach is dependent on whether the goal of the reaching movement is incorporated into actual activities of daily living and real-life objects, compared with imagined objects or reaches to nonmanipulation-based targets. Overall, the results of a number of studies in both stroke survivors and controls indicate that reaches that are incorporated into real-world activities of daily living are smoother, and better coordinated than reaches that are practiced outside of such a natural context (Lin et al., 1998, 2000; Trombly & Wu, 1999; Wu et al., 2000). These findings are particularly interesting when taken in the context of recent advances in virtual reality (VR) for rehabilitation training. Wu, Trombly, Lin, & Tickle-Degnen (1998) recently compared the kinematics of reaching to real and virtual objects. They demonstrated that both healthy subjects and stroke survivors with motor deficits used similar movement strategies when grasping and placing a ball in the two conditions. Taken together, these findings suggest that training of arm movements is best done in context of occupational tasks, but that VR environments may be a valid approach to exploiting such tasks in rehabilitation environments.

Another aspect of OT that can benefit from the incorporation of movement science is sensory integration (SI) theory and practice. SI, proposed by A. J. Ayres in the 1960s and 1970s, remains one of the most influential habilitation and rehabilitation approaches employed by occupational therapists. Sensory integration is grounded in the principles of nervous system growth, development, and functioning that were being validated in laboratory-based environmental enrichment studies using animal models. This knowledge, in turn, was complemented by Ayres's systematic work in assessment development, in building a data-based typology differentiating types of sensory integrative dysfunction, and in testing the effects of related therapeutic procedures on both proximal (e.g., eye-hand coordination) and distal (e.g., reading ability) outcomes (Ayres, 1972, 1975, 1979). Sensory integration theory purports that sensory contributions, particularly vestibular, proprioceptive, and tactile modalities, as well as attention, are all critical for adaptive perceptuomotor- and sensorimotor-related behaviors. This same proposition was, and continues to be, extensively researched in neuroscience (Lackner & DiZio, 2005) and cognitive psychology (Grush, 2005). For example, studies in patients with specific large fiber sensory neuropathies demonstrate the importance of proprioception in predictive control of limb dynamics as well as for motor adaptation (Ghez, Gordon, Ghilardi, & Sainburg, 1994; Ghez & Sainburg, 1995; Lefumat et al., 2016; Sainburg, Ghilardi, Poizner, & Ghez, 1995; Sainburg, Poizner, & Ghez, 1993; Sainburg, Ghez, & Kalakanis, 1999; Sarlegna, Malfait, Bringoux, Bourdin, & Vercher, 2010). Additionally, researchers have explained the importance of vestibular information in coordinating multiple upper limb segments for accurate reaching. This input is especially important during trunk movements where vestibular input is critical in making predictive decisions about movements (Lackner & DiZio, 2005). Finally, recent evidence in neuroscience indicates that neural processes that utilize proprioceptive and vestibular information to coordinate voluntary movements (via predictive and feedback-mediated control mechanisms) are lateralized in the brain and form the basic foundations of human

handedness (Duff & Sainburg, 2006; Sainburg, 2005, 2014; Yadav & Sainburg, 2014b). Ayres (1972) predicted that these sensorimotor processing deficits are associated with deficits in the development of consistent motor lateralization—a phenomenon that might reflect sensorimotor optimization (Sainburg & Eckhardt, 2005; Yadav & Sainburg, 2014a, 2014b).

As evidenced previously, compelling parallels exist between science that strives to understand control of voluntary movements and science and practice aimed at facilitating engagement in human occupation. In fact, neuroscience's influence on the development of the fields of OS and OT can be tracked by noting the topics of the American Occupational Therapy Association's major annual Eleanor Clarke Slagle (ECS) lecture is named for a pioneering founder of the profession. This lecture reflects "current ideas in the field ... by individuals who have creatively contributed to the development of the body of knowledge of the profession through research, education, and/or clinical practice" (American Occupational Therapy Association, n.d.). Following A. J. Ayres's innovative research integrating neuroscience into clinical intervention strategies (Ayres, 1963), Lorna Jean King expanded its applications to the mental health population (King, 1978). In her 1975 ECS lecture, Josephine Moore expounded on the complexities of the nervous and limbic system in terms that related to clinical application (Moore, 1975). In 1989, Farber (1989) subsequently advocated the integration of OT and neuroscience in her ECS lecture entitled, "Neuroscience and Occupational Therapy: Vital Connections," in which she argued that "[n]eurobiological information can be used to design research to evaluate our existing treatment philosophy and methodology and to develop new theories and technology [in occupational therapy]." Moreover, in 2001, Dunn (2001) delivered her ECS lecture, "The Sensations of Everyday Life: Empirical, Theoretical, and Pragmatic Considerations," which focused on understanding the sensory basis of human occupation. Finally, in 2015, Cohen (2015) eloquently described the role of scientific inquiry in OT theory and practice, providing examples of neuroscience research.

In keeping with the central theme of the aforementioned ECS lectures, we believe that the benefits of promoting increased integration of neuroscience, including movement science, and biomechanics, with OS/OT are substantial and will positively influence research in both disciplines. One of the obvious advantages of such integration is that neuroscience can provide precise, quantitative methods, beyond those already employed in OS and OT, for assessing occupational performance. In addition, it can also make available technologies, paradigms, and specialized equipment to gauge the functioning of specific neural mechanisms in the brain. In a complementary way, biomechanics offers techniques for objectively evaluating discrete parameters of motor function. Although OT and OS are broadly focused, measurement using these tools may prove useful for uncovering the mechanisms that contribute to or underlie changes in occupational performance. Reciprocally, the particular perspectives of OS and OT can help to expand the interpretation of basic neuroscience or biomechanical findings and pose clinically important applications. For example, an OT mindfulness intervention for stroke recovery may consider the effects of both mental and physical health on recovery. However, to measure the effects of mindfulness on the brain and body, brain imaging (e.g., electroencephalography) and biomechanics (e.g., kinematic measurements) techniques can be employed. In short, through further integration

of the fields, it is highly likely that very innovative and methodologically sophisticated studies of consequence may be undertaken, and that, ultimately and most importantly, patient care will appreciably improve.

PROPOSALS FOR MOVING FORWARD

Unfortunately, the integration of movement science with OS and OT has not been fully realized. Although there is very little objective data about membership affiliations and professional certifications available through the Society for Neuroscience or the Society for the Neural Control of Movement, very few individuals with OT or OS backgrounds are actively members. For example, occupational therapist attendance at the Society for Neuroscience's annual Neurorehabilitation Social has traditionally been extremely low; recently, in 2015, OT presence increased to only about eight of 300 participants, or less than 3% of attendees. The representation of occupational therapists at the Society for the Neural Control of Movement has been likewise. Consequently, the development of theory on the sensorimotor foundations for understanding human occupation and its application to OT interventions has been extremely limited.

Admittedly, the following strategies we propose to increase enrollment of occupational scientists and occupational therapists in movement science doctoral programs are conservative. We suggest that inclusion of mathematical, chemical, and physical science prerequisites for entry into OT professional programs may represent an important long-term objective to advance the scientific rigor of OT as a discipline. However, we also recognize that many occupational scientists and occupational therapists do not work with or focus on populations with motor dysfunction. Therefore, regardless of the potential benefits of increased scientific preparation, the immediate career objectives of some applicants may not necessitate academic preparation in physics, chemistry, and calculus. Recognizing that this issue is controversial, we restrict our current recommendations to the aggressive recruitment of individuals who have undergraduate degrees in the physical and biological sciences for entrance into OT entry-level graduate programs.

Such applicants will already have taken the coursework necessary to meet the requirements of their major field of study. We suggest that those particular OT academic programs that recruit and admit a critical mass of students with strong backgrounds in the physical and biological sciences chart out for these students a clear pathway through which they can easily transition into movement science doctoral study.

Second, we recommend that specialized academic programs be established for another subset of individuals who have not taken physical science courses, but who wish to pursue integration of knowledge from OT, OS, and movement science. In such programs, students would not only be prepared for entry into the OT profession, but, beyond this, they would also have taken the foundational courses that would enable them to be admitted to a movement science PhD program. A viable structure through which to offer such programs would be a combined OT doctorate and PhD program. Such specialized programs could be modeled after well-established MD/PhD programs and offered at competitive research institutions with the capacity to provide the necessary scientific mentorship.

The strategies detailed previously are proposed not as a final solution, but as first steps toward accelerating the integration of OS, OT, and movement science. If implemented, they should, in time, result in a critical mass of scientists who are well-trained to conceive of and conduct the innovative, interdisciplinary, translational research that these fields require. The manuscripts in this issue of *Journal of Motor Behavior* reflect the current state of the science. Readers may observe that traditional neural control of movement principles guide the research discussed in this publication. However, as the relationships among OT, OS, and movement science grow and strengthen, and as more occupational therapists pursue doctoral work in movement science, it is inevitable that novel and innovative ways of understanding task and occupational performance will emerge. In turn, this knowledge and its application hold great promise for improving patient care.

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FIGURE 1. Schematic of the International Classification of Function, Disability, and Health (ICF) and the role of movement science and occupational science in this scheme.