PSYCHOPHYSICS:
TOP-DOWN *AND* BOTTOM-UP ENABLE 'MEASURING THE IMPOSSIBLE'

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Abstract

'Measuring the Impossible' (MtI) refers to recent innovative research activities related to the measurement of quantities and qualities that are dependent on human perception and/or interpretation. Its interdisciplinary nature interconnects various monodisciplinary research areas; physics, physiology, mental part of psychology, and (overt) behavioral sciences. These four also depict the different aspects of inner and outer psychophysics. Outer psychophysics regards physiological and mental processing as a combined 'black box' within which no measurement is performed. A key question within MtI and in inner psychophysics is how to explicate the mental or psychophysiological processes taking place within the 'black box' and this is cardinal to developing new theories and methods of measurement. To accomplish this, we argue that the two traditional Bottom-Up and Top-Down approaches have to be integrated into a dual-directional Research Strategy Loop involving complex communication systems beyond the straight-forward psychophysical relationship.

What is 'Measuring the Impossible'?

'Measuring the Impossible' refers to new and innovative research activities related to the measurement of quantities and qualities that are dependent on *human perception and/or interpretation* (Rossi & Berglund, 2009). This includes, for example, perceived attributes of products and services, such as quality or desirability, and societal characteristics such as security or health. Measuring the Impossible (MtI) aims at consensus on how 'generic' metrological issues are currently applied or can be applied specifically to understanding, quantifying and predicting human perception and interpretation (i.e. 'Measurement of Persons'). Examples of 'generic' issues are (a) measurement concepts and terminology, (b) measurement techniques and instruments, (c) measurement uncertainty and reliability, and (d) decision making, impact assessment and validity (Pendrill et al., 2010). A key aspect of research in this area is that it must be of an interdisciplinary nature, involving, for example, investigations of human mental and brain functions (Blackmore, 2006; studied primarily in psychology and neuroscience), research into how these underpin human attention, perception and cognition (psychophysics and behavioral studies) and contribute to the development of measurement instrumentation and perceptual models (metrology, mathematics, modeling, computing, psychology, physics, and psychophysics). 'Measurement of Persons' has two meanings, on the one hand, 'Measuring various characteristics of the Person(s)'; on the other hand 'Person(s) used as a Measuring Instrument'. In the first meaning, the measurand relates to a person or population but may be physical (e.g., body weight; Snyder, 1975), physiological (e.g., heart rate), psychological (e.g., personality; Lord & Novick, 1968), social (e.g., sociability), or philosophical (e.g., capacity for original thought) in nature. In the second meaning, the measurand originates in human perception and/or interpretation, but is typically ‘attributed‘ to an external object or environment (e.g., quality or comfort of products), the society (e.g., information systems, cooperative climate, interactive behavior), other persons (e.g., movement, behavior, communication), or the persons themselves (e.g., emotions, logics, symptoms).

The interdisciplinary nature of MtI research raises many challenges. In many disparate disciplines/interdisciplines, related but so far unconnected developments have to be investigated and interlinked. For example, valid decision-making requires improved measurement based on human perception and/or human interpretation of qualitative information. In the development of research in the MtI field, it is essential that mechanisms are in place to facilitate interdisciplinary science communication and creativity, not only among researchers, but also in the evolving wider international community (Galanter et al., 2010).

Measurement Systems and Processes

A ‘process’ can be defined as a system that generates information (Bentley, 2005). Examples of information variables that are generated by physical and chemical processes are: (a) a moving car generates displacement, velocity and acceleration variables and (b) a chemical reactor generates temperature, pressure and composition variables. Similarly, a person can be considered to generate a number of information variables through perceptual, cognitive and emotional processes. Thus, sensory perception can be described as a process that generates information variables (Ward, 2002), such as environmental perceptions (e.g., odours from a pulp mill). Alternatively, sensory perception may also be described as a measurement system that typically consists of several elements or blocks: a sensing element (e.g. olfactory receptors in the nose), a signal-conditioning element (e.g. the olfactory bulb), a signal-processing element (e.g. the olfactory cortex of the brain) and finally a data-presentation element (brain-mind ‘bridging’ of neurobiochemical activity and the mental awareness of odours; the perception). The measurement system may also include between-element feedback loops and brain-mind interactive communication processes (Popper & Eccles, 1981). Understanding these types of dynamic measurement systems and processes lies at the centre of the ‘Measuring the Impossible’ research area.

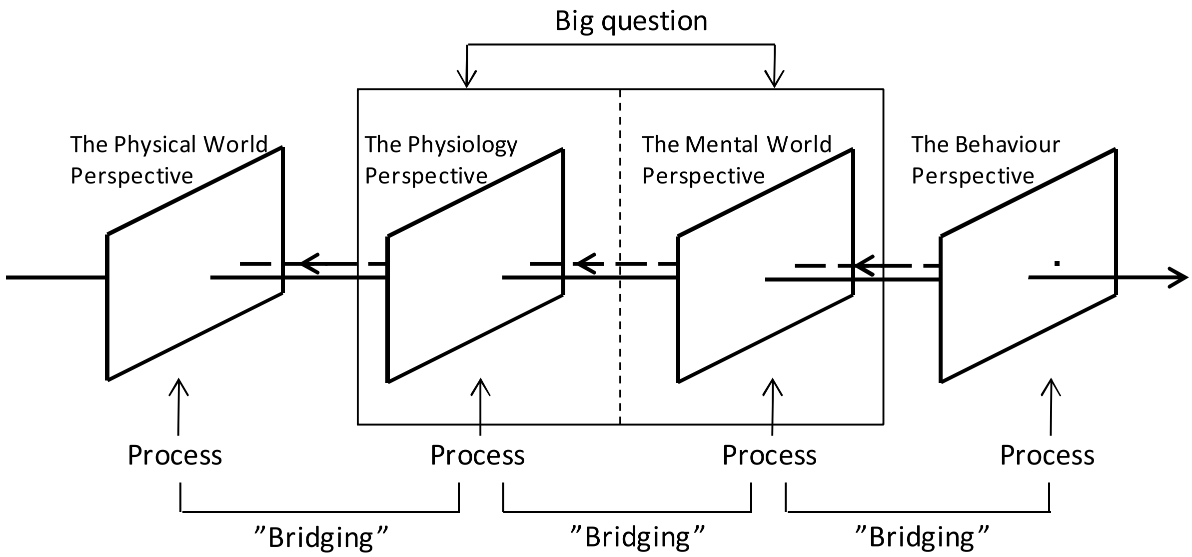

Fig. 1. Theoretical representation of the processes, interconnections and measurement systems that are involved in the ‘Measuring the Impossible’ area.

Figure 1 illustrates the various interconnections between four monodisciplinary research perspectives and associated measurement systems and processes that are of relevance for Measuring the Impossible. Each of the four planes represents physics, physiology, mental part of psychology, and (overt) behavioral sciences. In each of these four science areas there are phenomena and theories as well as processes and methods, which are applied and/or practiced in monodisciplinary research. Some of the processes are utilized in measurement systems. The square embracing the physiology and mental boxes represents processes 'inside' human being(s) and the dotted vertical line represents the brain-mind 'bridging'. Understanding this relationship is one of the 'big questions' in Measuring the Impossible. The behavior box here refers to overt behavior, which may be observed by other persons (e.g., a smiling face in snapshots or the reaction time in pressing a button).

Process-oriented research to measure behavior or characteristics of individuals or groups of persons has primarily taken place within the individual disciplines shown in Figure 1, that is, in physical, physiological, (mental) psychological, or (overt) behavioral sciences. Thus far, the main focus for interdisciplinary research has been on understanding the ways in which individual processes link together ('bridging' problems) using approaches in sensory physics, psychophysics and/or psychophysiology (Berglund et al., 2010). There are numerous examples in the field of sensory physics that are based on the use of psychophysical methods, for example, (a) understanding the relationship between the physical properties of materials and human sensory perceptions such as tactile, olfactory or pain sensations and (b) understanding how the physical attributes of an environment are linked to mental features and processes such as decision making through the study of overt behavior. Increasingly, these psychophysical experiments are being complemented with psychophysiological methods, such as the use of neurobiological and neuroimaging techniques to measure functions of the human brain in order to understand better the (mental) perceptual, cognitive or emotional processes.

Figure 1 also depicts the different aspects of inner and outer psychophysics, both of which have important contributions to make to the field of MtI. In inner psychophysics, the process starts from physical properties and has mental properties (perception, cognition, emotion etc.) as the output result. In outer psychophysics, the process also starts from physics but instead has behavior as the output result. Outer psychophysics thereby handles physiology and mental processing as a combined 'black box' within which no measurement is performed. A key question to be addressed within MtI is how to reveal the processes taking place within this 'black box'. That is, as illustrated in Figure 1, how to measure the two-way 'bridging' processes involved between the physiological processes and the mental processes and their outcomes (e.g., Popper & Eccles, 1981), and to understand how perception, cognition, learning, memory and emotions build bridges between them. This 'black box' issue has previously been overlooked in psychophysics, but is of utmost importance for developing new kinds of measurement procedures and instruments with capacities far beyond current methods and devices (Berglund et al., 2010). These will make it possible, for example, to measure how environmental conditions (soundscape, lighting quality, etc.) impact on feelings of comfort and wellbeing and thus to measure and model how these can be changed for maximum beneficial effect.

Interdisciplinary Research Strategy

Although a range of experimental methods, techniques, for data analysis, and models and methods of perceptual measurement have been developed during the past 150 years or so, there has been relatively little coordinated research aimed at developing a comprehensive

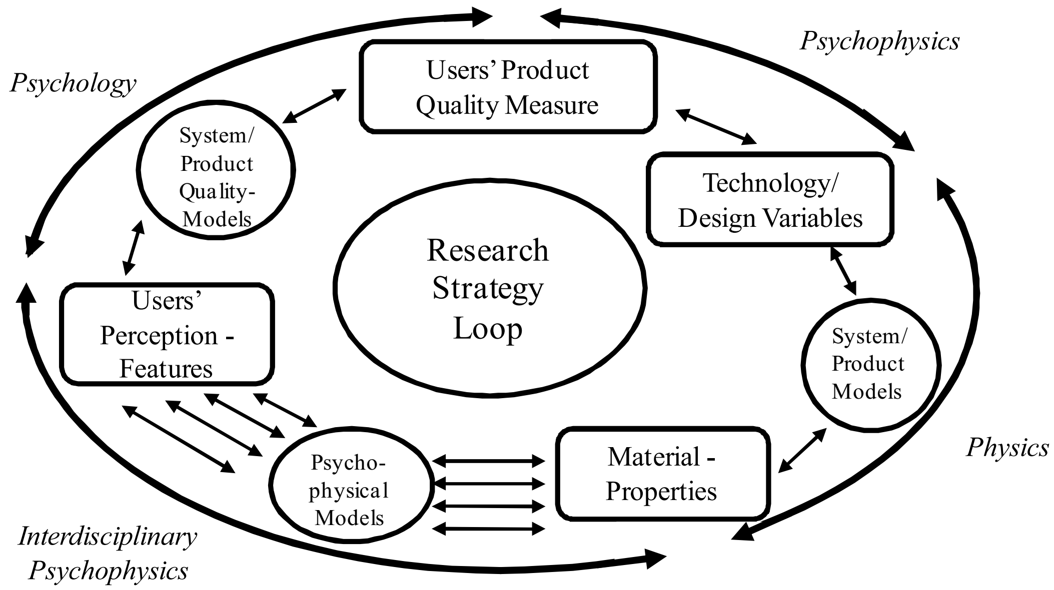

Fig. 2. The dual-directional Research Strategy Loop (RSL) involving complex connective systems.

understanding of human perception and interpretation. In real life, several human senses are alerted although the visual and auditory perceptions may dominate over, for example, odorous and tactile perceptions. Herein, we present a multisensory perception approach to measure a perceived feature, for example, product quality. We believe that multiple physical properties generate perceptual product features that are integrated and together build up the perceived product quality. Further, we anticipate that the perceived product quality may be restricted to the physical properties of a material. Through a two stage model (Berglund, 1974; Berglund et al., 1982), psychophysical relationships are used to translate material properties to corresponding material features, which in turn combine in a complex "mixture" model to perceived product quality.

To fully interconnect the physical properties to the users' perceived product quality of a resulting product, we propose the use of the Research Strategy Loop (RSL) depicted in Figure 2. The RSL may be used to explicate how to disentangle the key physical properties that determine the perceived quality of a specific product. The *Users' Product Quality Measure* will be connected to the *Technology/Design Variables* through a series of research steps (interconnecting boxes in Figure 2), by moving either clockwise or counterclockwise. The different research steps correspond to material properties or the users' perceptual features that are all controllable and measurable.

Technology/Design Variables are the factors we can control in the material manufacturing: type of material and its composition, blending with other material components, material architecture, etc. *Material – Properties* are quantitatively measurable (physical) properties, such as barrier properties, transparency, dyeability, ductility, impact strength, water susceptibility, degradability, surface roughness, etc. *Users' Perceptions – Features* are quantitatively measurable features of products that the user perceives: product adequacy, aesthetics, design values, preference, handling, color, durability, flexibility, sustainability, odor, surface feel, etc. *Users' Product Quality Measure* is the users' integrated evaluation of product quality. *System/Product Models* predict *Material Properties* from *Technology/Design Variables* using computer software, physical models or algorithms. An example question is: How would the product's (physical) toughness be influenced by a change in material? *System/Product Quality – Models* develop complex models that will be used to predict what specific user perception (features) are involved in user product quality. An example question is: What perceptual features are most critical for improving the quality of the product; the answer may be product adequacy combined with visual/tactile aesthetic appeal. In these models, it would be necessary to include individual differences among users, because of their interpretational nature. *Psychophysical Models* identify and predict perceptual features from measurable product properties (or the reverse). An example question is: How will a change in material influence the perceived handling of the product? At this stage, basic research information has to be generated on how systematic unidimensional change can be accomplished psychophysically. This knowledge is based on basic empirical data.

The truly innovative part of this research strategy is to integrate the two traditional Top-Down and Bottom-Up approaches in the Research Strategy Loop, and particularly to find communication channels between the two research approaches. The Top-Down approach starts in the *Users' Product Quality Measure* box and moves to the *Users' Perceptions – Features* and further counter-clockwise, whereas the Bottom-Up approach will start in the *Material – Properties* and move to the *Technology/Design Variables*, which at the end will connect with the *Users' Product Quality Measure*. The focus of the innovative interdisciplinary research will be the interplay between the *Material – Properties* and the *Users' Perceptions – Features*. Critical for research success is the coherence of the complex models for *Users' Product Quality Measure* and the complex models for *Technology/Design Variables*.

Measuring the Impossible Enabled

The dual-directional Research Strategy Loop presented herein provides an important milestone for the understanding on how to measure the impossible, that is, measurement of quantities and qualities that are dependent on *human perception and/or interpretation*. The interdisciplinary nature of Measuring the Impossible forms the ideal platform for combining the two traditional Top-Down and Bottom-Up approaches and thereby forming an integrated measuring system out of previously disparate parts. The most important part of measurement was not dealt with in this paper, that is, the person(s) who should actually conduct the measurements of perceptions and interpretations of phenomena and processes. Our current view is that one person is a unique measuring instrument. The logics behind this statement is that averages of measures from many persons will provide information on the measurand for the group of persons. But, from a measure based on group data (theory and method), it is of course not possible to deduct what measures were provided by the individuals constituting the group. This knowledge is however necessary for designing product quality.

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