Trends in Cognitive Sciences

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Scientific Life

Data-Driven Methods to Diversify Knowledge of Human Psychology

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Psychology aims to understand real human behavior. However, cultural biases in the scientific process can constrain knowledge. We describe here how data-driven methods can relax these constraints to reveal new insights that theories can overlook. To advance knowledge we advocate a symbiotic approach that better combines data-driven methods with theory.

Cultural Lenses and Constrained Paradigms

The explicit aim of the scientific process is to obtain an accurate understanding of the world. Nevertheless, as discussed in metaphysics, philosophy of science, and cognitive science, this process is, by virtue of its human construction, inherently subjective because knowledge is generated through the narrow lens of our prior experiences and beliefs [1]. Hypothesis testing – a key component of the research process – can further tighten these constraints and erect echo chambers of scientific knowledge. Because knowledge of psychology – theoretical, methodological, and empirical – has been developed mostly in Western societies [2], it is focused on a subset of the human population described as Western, educated, industrialized, rich, and democratic (WEIRD) [3]. Recent discoveries of cultural differences in psychological phenomena that were once considered to be universal highlight the inherent subjectivity of the scientific process and the need to use approaches that allow natural variation to surface to permit a more accurate understanding of human psychology.

To relax the constraints of the dominant Western-centric lens, the cognitive sciences have called for broader samples of the human population, more diverse research teams, and better-fitting indigenous lenses to guide the scientific process in different societies [4]. While each undoubtedly contributes to the diversification of knowledge, theory-driven lenses – the hallmark of hypothesis testing – can constrain the development of knowledge, even within a culture. This poses a conundrum: if psychological researchers are bound by cultural lenses, how can they better equip their toolboxes to explore new and unfamiliar psychological lands?

Relaxing Theory-Driven Constraints

One approach to alleviating the constraints of theory-driven research is to adopt a more agnostic stance that relaxes theoretical constructs and uses methods that allow more freedom of exploration. For example, as illustrated in Box 1, understanding which facial expressions communicate emotions in different societies can involve selecting facial expression stimuli agnostically – that is, without using the prior assumptions of Western theory that six specific facial expressions represent six specific emotions [5]. Participants can then select from a broader array of stimuli the facial expressions that accurately represent the emotion categories that are relevant in their society. Similarly, in studies of music and body movements, participants can freely generate representations of concepts themselves, such as manipulating the rate, pitch, and composition of piano notes to 'make the music sound happy' [6]. Open-ended methods that ask questions such as 'what is this smell?' [7] or 'what does this person feel?' [8] can also give participants the freedom to respond outside the boundaries of culturally prescribed response options.

Crucially, these more agnostic approaches aim to lift the boundaries of a theory-driven agenda to allow new knowledge to emerge that might otherwise have been overlooked – a particularly valuable approach when challenging entrenched theories and fundamental assumptions. This philosophically grounded approach has been formalized most in the field of psychophysics – a discipline that aims to derive law-like relationships between objectively measurable stimuli in the external environment and subjective human sensation; that is, to establish the transfer functions of the physical to the psychological world. To achieve this, psychophysical methods tend to exhaustively explore the parameters of a stimulus and measure subjective responses to it such as vision, hearing, taste, or touch. A classic example is the contrast sensitivity function, which shows how the ability of the human visual system to detect changes in contrast depends on the spatial frequency content of the stimulus. To derive this function, observers are usually presented with a series of sinewave gratings (i.e., parallel stripes) that vary on two parameters: spatial frequency (stripe width) and contrast (stripe brightness, from black to white) and are asked to detect the presence of stripes. Many such gratings are generated by thoroughly sampling the 2D stimulus parameter space of spatial frequency and contrast, and are tested against the full spectrum of perception from none to threshold to saturation. This rigorous exploration of the relationship between stimulus information and subjective sensation therefore has several advantages that make them well suited to the challenges of diversifying psychological knowledge beyond WEIRD populations (Box 2 gives a recent example). We highlight four of these advantages below.

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Box 1. A Research Program Constrained by Theory: The Universality of Six Facial Expressions of Emotion

A clear example of how a theory-driven approach can constrain knowledge is research on the universality of facial expressions of emotion. Based on Darwin's theory of the biological and evolutionary origins of facial expressions, the human facial expressions are pan-cultural signs of basic emotions such as happy, angry, and sad [13]. To test this theory, Western researchers selected a small set of facial expressions that they theorized as representing six specific emotions, and asked people in different societies to match these images to the proposed emotion labels in a forced-choice task. Numerous studies using this popular approach showed that Western participants consistently matched the facial expressions with their hypothesized emotion labels. By contrast, many non-Western societies showed less agreement overall – for example, smiles were interpreted as happiness, whereas the nose scrunches, scowls, and wide eyes were not consistently recognized as disgust, anger, or fear as hypothesized ([14] for review). Figure IA shows the distribution of recognition accuracy for these six facial expressions of emotion across different societies (Figure IB for examples).

With many of the facial expressions being recognized at above chance levels, these six specific facial expressions became widely known as the universal language of emotion, recognizable anywhere in the world. However, the patterns of recognition performance across different societies suggest that these particular facial expressions and their corresponding emotion labels most accurately reflect those used in Western society – perhaps unsurprisingly given that Western theorists selected the facial expressions and emotion labels tested in the experiments.

Thus, while this cross-cultural research tested a broader sample of the human population, its theory-driven approach introduced a cultural bias that restricted both the sampling of stimuli and the response options, and thus reduced the possibility for other knowledge to surface that could more accurately represent other societies [15]. Consequently, knowledge of human facial expressions of emotion has remained confined to a small subset of six static facial expressions and six emotion labels proposed by Western theorists. Box 2 illustrates how recent data-driven methods have been used to relax the constraints of this theory-driven approach to explore more broadly how facial expressions communicate emotions in different cultures, and to reveal both their cross-cultural components and specific accents.

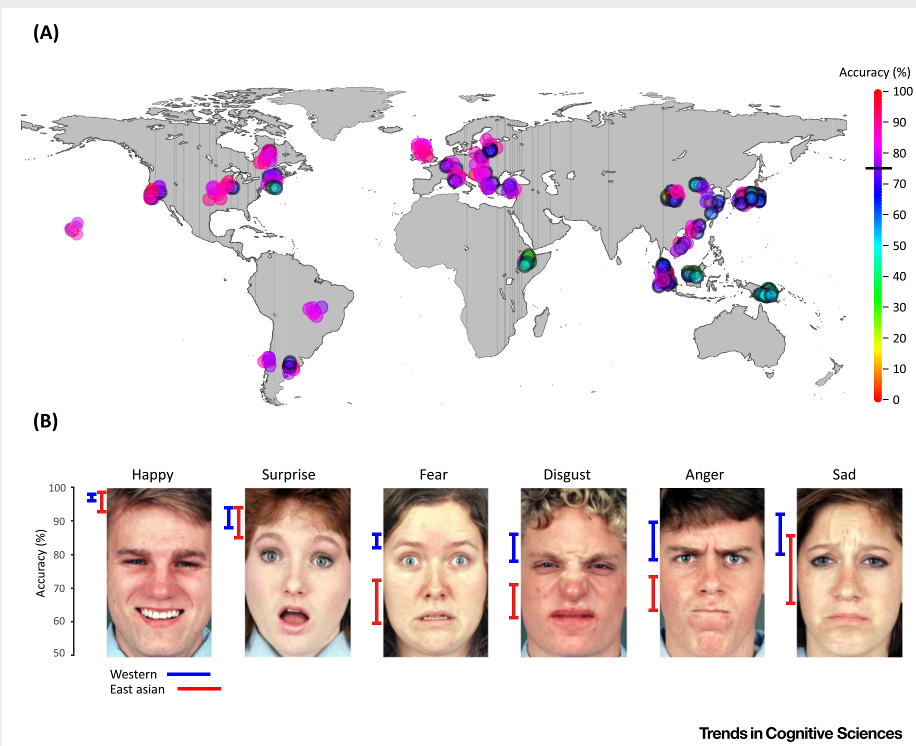


Figure I. Recognition Accuracy of the Six Universal Facial Expressions of Emotion across Cultures. (A) Color-coded circles show the average recognition accuracy of each of the six universal facial expressions of emotion in different parts of the world (see colorbar to the right). Circles outlined in black indicate performance below 75%. Figure reproduced, with permission, from [14]. (B) Recognition Accuracy of the Six Universal Facial Expressions of Emotion in Western and East Asian Culture. Each face shows an example of the standardized universal facial expressions of the six basic emotions (see labels above each face) used in these studies. Blue and red bars to the left of each face show the variance of recognition accuracy (median absolute deviation) in Western (blue) and East Asian (red) culture.

Few *A Priori* Assumptions

Psychophysical methods often sample stimulus parameters agnostically – that is, with few *a priori* assumptions about what stimulus information will drive a response. This allows other possibilities to be explored and a chance for new and unexpected knowledge to surface. Such an approach makes intuitive sense not only for the purposes of objective investigation but particularly for exploring unfamiliar societies. For example, using Western beauty ideals to investigate which female physiques are desirable worldwide would not capture the much larger body shapes that are considered desirable in some African countries. Data-driven approaches would instead sample the wider range of natural human body shapes and test them against perceptions of beauty across societies. Doing so would reveal a map of beauty ideals across the world that could inform the biological and cultural origins of attraction.

Pan-Cultural

Data-driven methods are generic and can therefore be adapted to almost any physical or psychological environment [9]. For example, different odors, flavors, textures, and auditory and visual signals can be generated from a defined information space (e.g., RGB values for color) and tested not only against the various senses of smell, taste, touch, vision, and hearing but also against neural and physiological activity or even more complex responses such as approach and avoidance behaviors. These methods are also highly adaptable to navigating new research questions because stimulus information can be sampled in different ways – for example, parts of a body can be exposed with randomly placed apertures, or noise could be added to the body shape to alter its features; novel body shapes could be generated from a model of human body shape and color. Thus, the various shapes, sounds, smells, and colors found in different socioecological niches could be measured, parameterized, sampled, and tested against responses relevant to members of that society depending on the research question.

Symbiotic Relationship with Theoretical and Empirical Knowledge

Data-driven methods aim to relax the constraints of a theory-driven approach, but are not atheoretic. Instead, to avoid the curse of dimensionality and to provide tractable solutions, data-driven methods are often guided by theoretical predictions and existing knowledge (an example is given in Box 2). For example, sampling body shapes to test them against perceptions of beauty makes the explicit prediction that such judgments are based, at least in part, on body shapes. The body shapes sampled would also usually be within the limits of biological possibility as informed by existing knowledge. Such methods therefore provide an excellent complement to any theory-driven approach because they allow researchers to acknowledge theoretical constructs while keeping a relatively open mind.

Common Grounds for Comparison

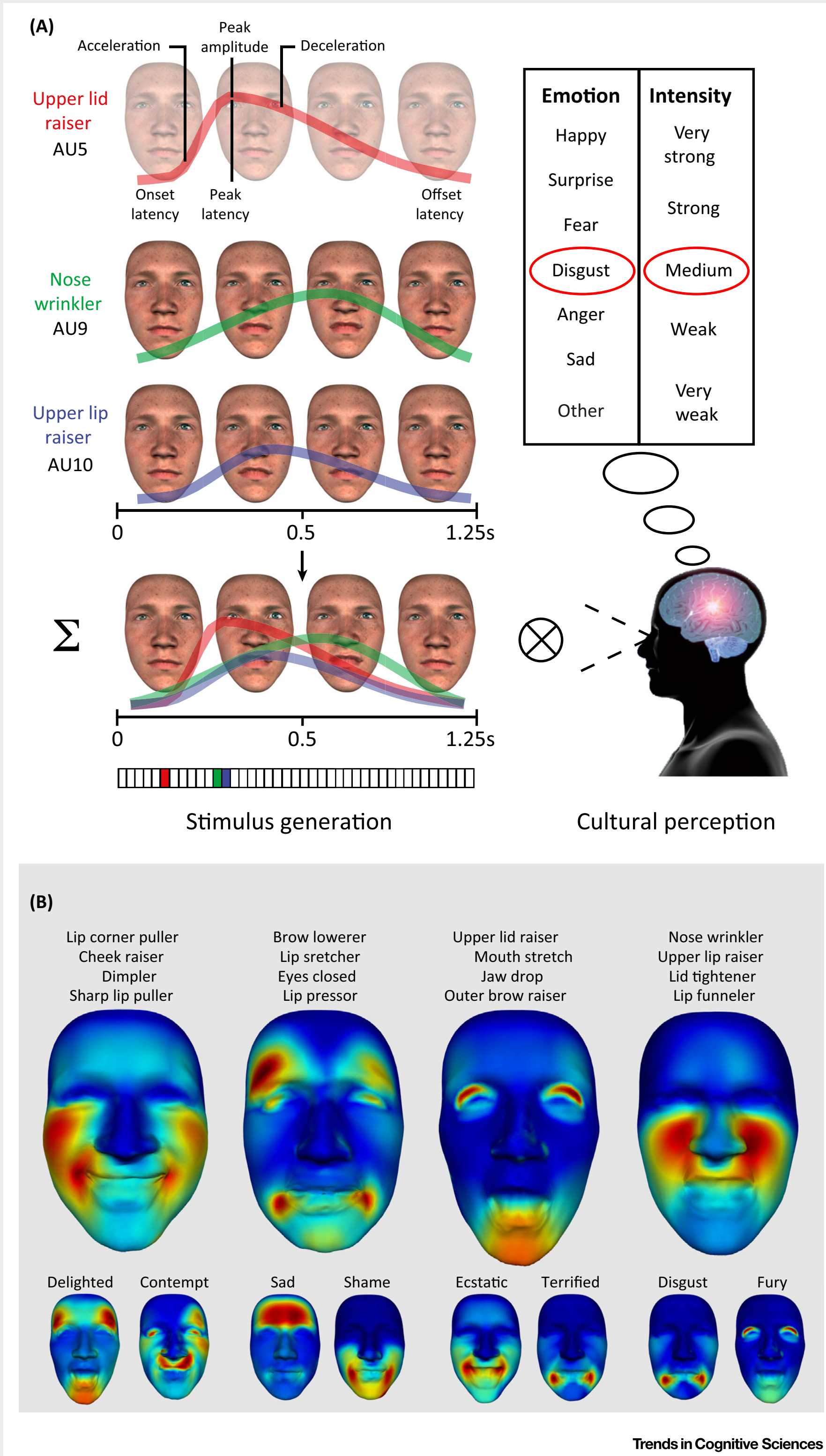
To establish the basic principles of human psychology it is necessary to compare the psychological worlds of different societies . However, narrower theoretical lenses that provide incomplete descriptions can make such comparisons problematic. By contrast, data-driven methods derive knowledge from objectively measurable information spaces and deliver quantitative measures of human behavior. For example, sampling the stimulus parameter space of color, dynamic face movements, vocalizations, or multivariate dimensions of 3D body shape could provide precise information ontologies of human behaviors based on a common information space that can be precisely and objectively compared across different societies.

Future Challenges: Realizing the Potential of Data-Driven Methods

With the recent maturation of data-driven methods and computational advances that make analysis of complex data

Box 2. Using Data-Driven Methods to Explore Facial Expressions of Emotion across Cultures

Understanding human facial expressions, particularly their cross-cultural components and specific accents, requires a broad exploration of face movements and the labels ascribed to them in different societies. Although the human face is capable of generating a large number of complex dynamic patterns, theory-driven methods have only tested a small subset. To gain traction on this complex task, this classical method can be given a psychophysical twist to provide the objectivity of data-driven methods with the structure of theory. Figure IA illustrates such an approach, called reverse correlation, which samples the parameter space of facial expressions, defined as individual Action Units (AUs) plus their temporal parameters, and tests them against the perception of emotion in different societies. Statistical tools, such as correlation or mutual information, can then be used to build a relationship between the dynamic AUs presented on each trial and the responses of the observer (e.g., here, the six classic emotions). This then produces a mathematical model of the stimulus properties that drive behavior – in this case, an information ontology of emotion perception. The resulting dynamic facial expression models are therefore represented quantitatively – here, as 1×42-dimensional binary vectors detailing the AU composition, plus values detailing the dynamic activation of each AU – which allows precise analyses and objective comparisons across societies. For example, to discover the facial expressions that are common across cultures and their accents, multivariate data reduction techniques (e.g., factor analysis) applied to facial expression models of 60+ emotions across Western and Eastern culture [5] revealed four latent expressive patterns (Figure IB, face maps in top row). Segregating out these core patterns also revealed how specific accents modify them to produce more socially sophisticated facial expressions such as 'delighted', 'shame', and 'fury'. Thus, by relaxing a theory-driven approach and exploring facial expressions and their labels more broadly, these data question the widely held view that six facial expressions are universal, and instead suggest that four latent expressive patterns are common across cultures.



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tractable [5,11], this approach can now provide powerful solutions to broadening scientific investigation. To fully realize its potential, a next challenge will be to creatively adjust these methods for use across the different subdisciplines of the cognitive sciences (e.g., psychology, neuroscience, linguistics, artificial intelligence) and in different human societies. To aid in this challenge, technological advances could support the collection of data across multiple and distant sites. For example, wearable non-intrusive devices designed for different ecological niches could objectively measure a variety of behaviors such as social proximity, hand and arm gestures, and eye movements. Widening scientific lenses can also be achieved by importing knowledge from neighboring scientific disciplines such as anthropology, biology, linguistics, physics, engineering, and computer science. For example, integrating behavioral ecology into the study of facial expressions has diversified concepts of their function [12].

Conclusions: Discovering New Lands

Decades of evidence and appeals from scholars in several subdisciplines of the cognitive sciences demonstrate that the psychological science community can no longer overlook the inextricable role of culture in shaping human perception, thought, and action. To understand and represent the diversity of human psychology, the discipline must undergo a significant conceptual and cultural shift to relax the constraints of a theory-driven approach, and achieve its ultimate goal as a scientific discipline – a deep understanding of human behavior from universal laws to cultural complexity.

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Figure I. (A) Data-Driven Modeling of Dynamic Facial Expressions of Emotion. On each experimental trial a dynamic facial expression generator [10] creates a random facial animation by randomly sub-sampling a set of individual face movements called Action Units (AUs) – here, Upper Lid Raiser (AU5), Nose Wrinkler (AU9), and Upper Lip Raiser (AU10) – and by assigning a random movement to each AU using several temporal parameters (see labels illustrating the red curve). The randomly activated AUs are then combined to produce a facial animation (see bottom row of faces) which the cultural observer categorizes by emotion and rates by intensity (here, 'disgust' and 'medium' intensity) if it matches their prior knowledge of that facial expression. Otherwise, they select 'other'. Statistical tools can then be used to build a relationship between the dynamic AU patterns presented on each trial and the observer's responses to deliver a precise mathematical model of the face movement patterns that communicate emotions to individuals within a society. These models can then be precisely analyzed to reveal the cross-cultural facial expression patterns and their specific accents. (B) Cross-cultural facial expression patterns and specific accents. Color-coded face maps (top row) show four core facial expression patterns associated with 60+ emotions across two distinct societies (Western and East Asian). The bottom row of faces shows the specific accents that modify each core expressive pattern to create different facial expressions such as 'contempt', 'shame', 'ecstatic', and 'fury'.