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BIOMETRIC RESEARCH PLATFORM

Human Behavior

POCKET GUIDE

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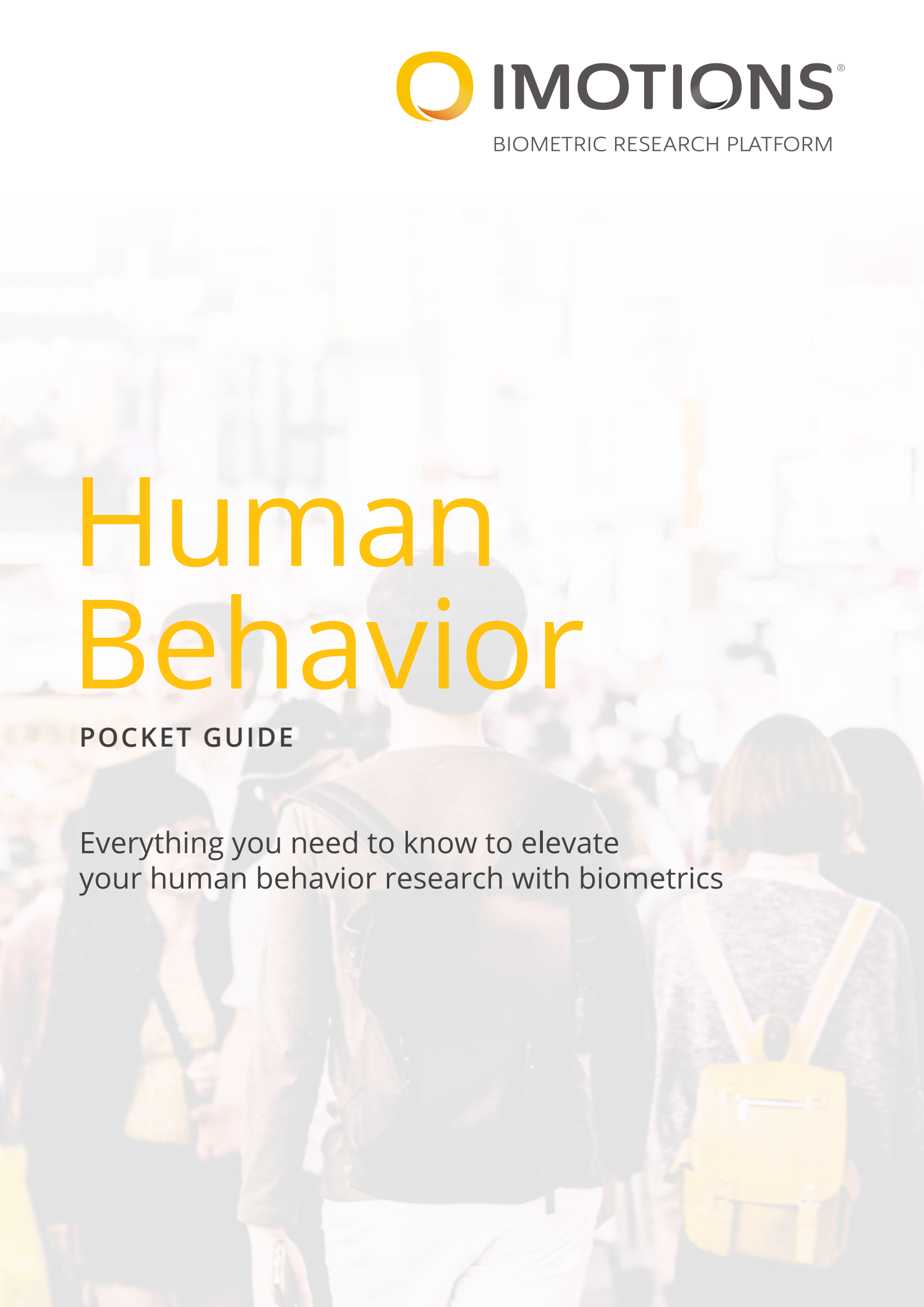
Everything you need to know to elevate
your human behavior research with biometrics



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iMotions Biometric Research Platform

Introduction

Academic and commercial researchers alike are aiming towards a deeper understanding of how humans act, make decisions, plan, and memorize. Advances in wearable sensor technology along with procedures for multi-modal data acquisition and analysis have lately been enabling researchers all across the globe to tap into previously unknown secrets of the human brain and mind.

Still, as emphasized by Makeig and colleagues (2009), the most pivotal challenge lies in the systematic observation and interpretation of how distributed brain processes support our natural, active, and flexibly changing behavior and cognition.

We all are active agents, continuously engaged in attempting to fulfill bodily needs and mental desires within complex and ever-changing surroundings, while interacting with our environment. Brain structures have evolved that support cognitive processes targeted towards the optimization of outcomes for any of our body-based behaviors.

So what exactly is behavior?

In simple terms, any observable action (or active movement) can be regarded as behavior - drinking coffee, talking on the phone, driving a car, typing on a computer, cleaning up the apartment, skipping rope.

Following that definition of behavior, it is rather surprising that when parents tell their children to “behave“, they typically want them to sit still, upright and obey to social expectancies (“no running around in restaurants and behaving like a bull in a china shop”) - actually quite the opposite from active behavior. Even then, however, there are observable indicators that signal behavior: They reluctantly sit down at the table, straighten their back and pull a sad face.

Stretching the general usage of the term behavior, the scientific definition of behavioral processes obviously roots deeper than what’s obvious to our eye.

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PART I:
Human Behavior

Actions, cognitions & emotions

In scientific research, human behavior is a complex interplay of three components: actions, cognitions and emotions.

Sounds complicated? Let's address them one by one.

Actions are behavior

An action denotes everything that can be observed, either with bare eyes or measured by physiological sensors. Think of an action as an initiation or transition from one state to another - at a movie set, the director shouts "action" for the next scene to be filmed.

Behavioral actions can take place on various time scales, ranging from muscular activation to sweat gland activity, food consumption, or sleep.

Even subtle bodily changes on a sub-second scale that aren't conscious to us can be considered behavior. They just happen to take place on different levels of granularity and with different time resolution. All of these processes in conjunction allow us to respond appropriately to our surroundings and follow our desires.

Often, actions are associated with perceptual processes - we turn up the volume when listening to our favorite song to blend out disturbing noise in the surroundings, we close our eyes to smell our favorite dish standing in front of us on the table.

Cognitions are behavior

Cognitions describe thoughts and mental images you carry with you, and they can be both verbal and nonverbal. “I have to remember to buy groceries,” or “I’d be curious to know what she thinks of me,” can be considered verbal cognitions. In contrast, imagining how your house will look like after remodeling could be considered a nonverbal cognition.

Cognitions comprise skills and knowledge - knowing how to use tools in a meaningful manner (without hurting yourself), singing karaoke songs or being able to memorize the color of Marty McFly’s jacket in “Back to the Future“ (it’s red).

Cognition extends beyond the languages you speak, the objects you interact with and the places you remember. Cognition allows you to create entirely new things just from your mind, to fantasize about a potential future or alternative universes, to invent and imagine a world that doesn’t exist.

Plans, desires, ideas, and interpretations are results of our cognitive skill set. Cognitions comprise problem-solving strategies, intelligence, and our personality – everything that makes you *you*.

Cognitive development and plasticity heavily depend on your body with which you experience your surroundings (embodied cognition). A blind person might cognitively represent their world completely differently from a person who’s able to see. Contrary to actions, cognition cannot be observed or measured directly – it can only be inferred indirectly from behavior.

Emotions are behavior

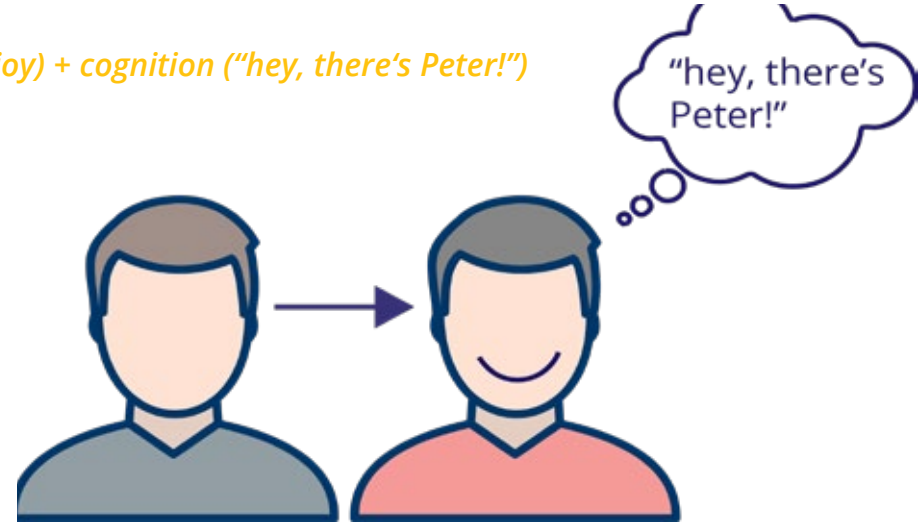
Commonly, an emotion is any relatively brief conscious experience characterized by intense mental activity, and a feeling that is not characterized as resulting from either reasoning or knowledge. This usually exists on a scale, from positive (pleasurable) to negative (unpleasant).

You become aware of increased levels of emotional arousal whenever confronted with life-threatening, fearful events or stimuli of high sexual appeal and bodily pleasure. Emotions are the essence of what makes you human. Facial expressions are heavily affected by emotions like joy, anger, surprise, fear, disgust, sadness or contempt – all of which can be observed directly.

Other aspects of physiology that are indicative of emotional processing - such as increased heart rate or respiration rate caused by increased arousal - are usually hidden to the eye. Similar to cognitions, emotions cannot be observed directly. They can only be inferred indirectly by tracking facial electromyographic activity (fEMG), analyzing facial expressions, monitoring arousal using ECG, galvanic skin response (GSR), respiration sensors, or self-reported measures, for example.

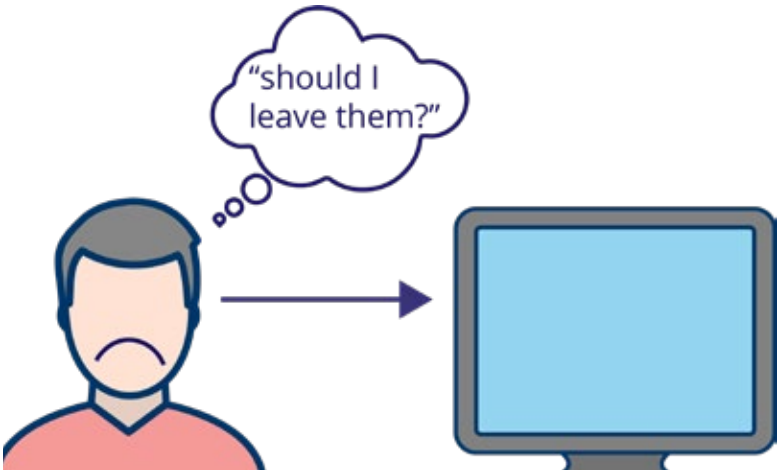
Actions, cognitions and emotions do not run independently of each other – their proper interaction enables you to perceive the world around you, listen to your inner wishes and respond appropriately to people in your surroundings. However, it is hard to tell what exactly is cause and effect - turning your head (action) and seeing a familiar face might cause a sudden burst of joy (emotion) accompanied by an internal realization (cognition):

action = emotion (joy) + cognition ("hey, there's Peter!")



In other cases, the sequence of cause and effect might be reversed: Because you're sad (emotion) and ruminating on relationship issues (cognition), you decide to go for a walk to clear your head (action).

emotion (sadness) + cognition ("I should go for a walk") = action



Scientific studies have ingeniously shown how cognitive skills affect bodily processes, how behavior changes cognition and how emotional awareness alters behavior.

Each of these processes are therefore intertwined, with each affecting another. This means that if we want to understand a behavior, we should examine the bodily processes, cognition, and emotions. Likewise, if we want to understand an emotion, we should investigate cognition, behaviors, and bodily processes.

There is also substantial evidence that cognitive activity and brain changes go hand in hand: Maguire and colleagues (2006) found that the hippocampus (a brain structure involved in spatial navigation) to be significantly increased for London taxi drivers who were required to memorize the entire city map. However, it is yet to be investigated whether driving a taxi boosted their hippocampus, or if people with larger hippocampal brain regions were more attracted to jobs with high memory demands.

Takeaways: What you should know...

Humans are active consumers of sensory impressions

You actively move your body to achieve cognitive goals and desires, or to get into positive (or out of negative) emotional states. In other words: While cognition and emotion cannot be observed directly, they certainly drive the execution of observable action. For example, through moving your body to achieve cognitive goals and desires, or to get into positive (or out of negative) emotional states.

Cognitions are specific to time and situations

New information that you experience is adapted, merged and integrated into your existing cognitive mindset. This allows you to flexibly adapt to and predict how events in the current environment may be influenced by your actions. Whenever you decide to carry out an action, you accomplish the decision in a timely, environment- and situation-appropriate manner. Put differently: Your cognitive system has to manage the dynamic interplay of flexibility and stability.

The former is important as you have to couple responses dynamically to stimuli, dependent on intentions and instructions. This allows you to respond to one and the same stimulus in near-unlimited ways. Stability, by contrast, is crucial for maintaining lasting stimulus-response relationships, allowing you to respond consistently to similar stimuli.

Imagination and abstract cognition are body-based

Even abstract cognitions (devoid of direct physical interaction with the environment) are body-based. Imagining limb movements triggers the same brain areas involved when actually executing the movements. When you rehearse material in working memory, the same brain structures used for speech perception and production are activated (Wilson, 2001).

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PART II:
Learning theories

Learning and behavior

When we talk about behavior, we need to consider how it is acquired. Learning denotes any acquisition process of new skills and knowledge, preferences, attitudes and evaluations, social rules and normative considerations.

You surely have heard of the “nature – nurture” debate - in the past, there has been quite some fighting about whether behavior was solely driven by genetic predispositions (nature) or environmental factors (nurture).

If behavior was solely driven by nature, your behavior (meaning your actions, cognitions and emotions) would be determined simply by your genes, similar to hair and eye color or height. Researchers arguing for genetic predispositions are also referred to as “nativists”.

Nativist researchers assume that characteristics that are not observable at birth (but emerge later in life) are regarded as the unalterable product of maturation. Maturation is believed to occur despite what happens around us.

By contrast, those arguing for the strong impact of nurture on human behavior assume that environmental factors such as education and social interaction solely drive our behavior. This position implies that anyone can become anything. All of us start as a “tabula rasa” - a clean slate - before we are shaped and molded by our surroundings into a specific personality and skill set.

Today, it’s no longer a question of either/or. There simply is too much evidence for the impact of nature and nurture alike - behavior is considered to be established by the interplay of both factors.

Current theoretical frameworks also emphasize the active role of of the agent in acquiring new skills and knowledge. You are able to develop and change yourself through ongoing skill acquisition throughout life, which can have an impact on a neurological level. Think of it as assigning neuroscientific processes to the phrase “practice makes perfect“.

Classical conditioning

Classical conditioning refers to a learning procedure in which stimulus-response pairings are learned - seeing tasty food typically triggers salivation (yummy!), for example. While food serves as unconditioned stimulus, salivation is the unconditioned response.

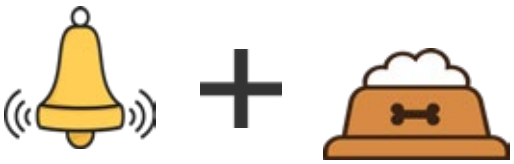
unconditioned stimulus -> *unconditioned response*

seeing food -> *salivation*

If encountering food is consistently accompanied by a (previously) neutral stimulus such as ringing a bell, a new stimulus-response pairing is learned.

unconditioned stimulus + conditioned stimulus -> *unconditioned response*

seeing food + hearing bell -> *salivation*



The bell becomes a conditioned stimulus and is potent enough to trigger salivation even in absence of the actual food.

conditioned stimulus -> *response*

hearing bell -> *salivation*

Described as generalization, this learning process was first studied by Ivan Pavlov and team (1927) through experiments with dogs, which is why classical conditioning is also referred to as Pavlovian conditioning.

Today, classical conditioning is the most widely understood of the basic learning processes.

Operant conditioning

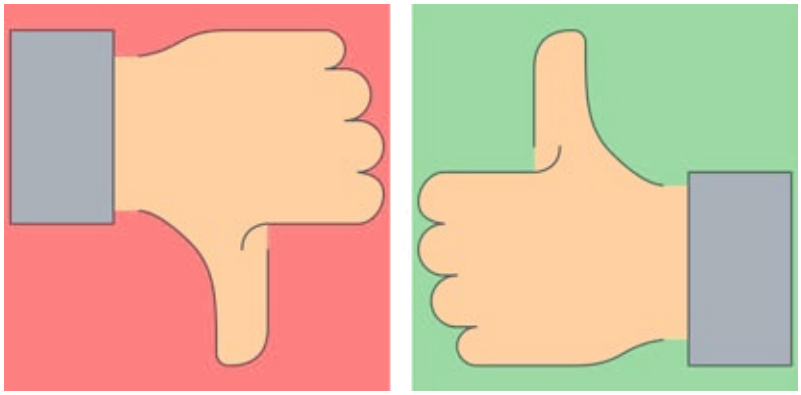
Operant conditioning, also called instrumental conditioning, denotes a type of learning in which the strength of a behavior is modified by the consequences (reward or punishment), signaled via the preceding stimuli.

In both operant and classical conditioning behavior is controlled by environmental stimuli – however, they differ in nature. In operant conditioning, behavior is controlled by stimuli which are present when a behavior is rewarded or punished.

Operant conditioning was coined by B.F. Skinner. As a behaviorist, Skinner believed that it was not really necessary to look at internal thoughts and motivations in order to explain behavior. Instead, he suggested to only take external, observable causes of human behavior into consideration.

Being heavily influenced by the work of E. Thorndike, Skinner used the term operant to refer to how we acquire the range of learned behaviors we exhibit each and every day.

According to Skinner, actions that are followed by desirable outcomes are more likely to be repeated while those followed by undesirable outcomes are less likely to be repeated. In this regard, operant conditioning relies on a fairly simple premise: Behavior that is followed by reinforcement will be strengthened and is more likely to occur again in the future.



The key concepts of operant conditioning are:

1. **Positive reinforcement (reinforcement)** occurs when a behavior is rewarding, increasing the frequency of that behavior.
2. **Negative reinforcement (escape)** occurs when a behavior is followed by the removal of an aversive stimulus, increasing the frequency of the behavior.
3. **Punishment** occurs when a behavior is followed by an aversive stimulus, causing a decrease in that behavior.
4. **Penalty** occurs when a behavior is followed by the removal of a rewarding stimulus.
5. **Extinction** occurs when a behavior that had previously been reinforced is no longer effective.

Social learning

Albert Bandura (1977) introduced the social learning theory to emphasize that humans learn through observing others' behavior, attitudes and outcomes of those behaviors. Most human behavior is learned observationally through modeling. For example, children pay attention to adult models and encode their behavior. At a later time, they may imitate the behavior they have observed.

Necessary conditions for effective modeling according to Bandura's social learning theory include:

1. **Attention** is modulated by various factors, including distinctiveness, affective valence, prevalence, complexity and functional value. Your intrinsic characteristics such as sensory capacity, arousal level, perceptual set and past reinforcement certainly affect your attention.

2. **Retention** denotes how well you remember the things you paid attention to. It includes symbolic coding, mental images, cognitive organization, symbolic rehearsal and motor rehearsal.

3. **Reproduction** includes physical capabilities along with self-observation of reproduction.

4. **Motivation** comprises past, promised and vicarious motives. If the vicarious reinforcement is not seen to be important enough to the observer, the behavior will not be imitated.

In adulthood, we form an idea of how new behavior is performed by observing others. Later, this coded information serves as a guide for action. In contrast to conditioning where there are only stimulus-response associations, social learning theory explains human behavior in terms of continuous reciprocal interaction between cognitive, behavioral and environmental influences.

Conclusion

These learning theories give guidance for knowing how we gather information about the world. The way in which we learn is both emotionally and physiologically appraised. This will have consequences for how we act, and carry out behaviors in the future - what we attend to, and how it makes us feel.

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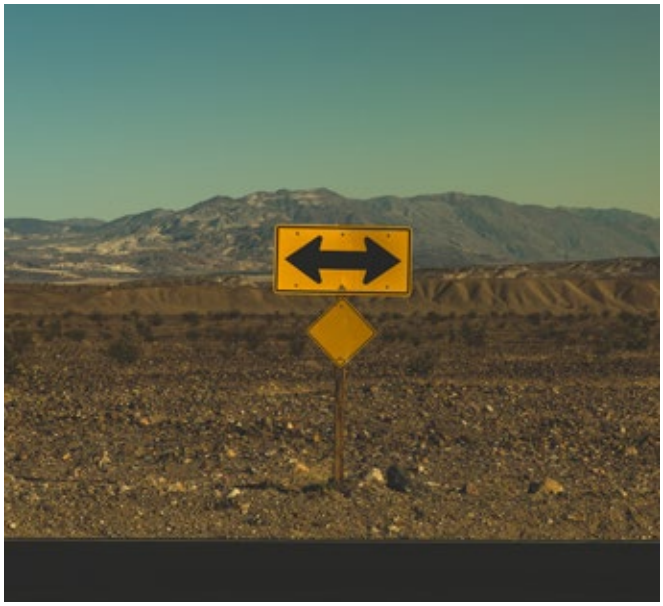
PART III: Decision-making

Decisions and behavior



While behavior is acquired through learning, whether the acting individual actually decides to execute an action or withhold a certain behavior is dependent on the associated incentives, benefits, and risks ("if Peter was penalized for doing this, I certainly won't do it!").

But which are the factors driving our decisions? Social learning theory already provides a base set of features, but one of the most influential psychological papers about decision-making was actually published in an economics journal.

In 1979, Kahneman & Tversky developed and published their model of decision-making - the Prospect Theory.

The Prospect Theory posits that humans choose based on risk. Decisions are taken based on the probability of potential gains or losses as opposed to the overall outcome, and these risks are assessed using heuristics.

According to Kahneman & Tversky, the majority of human error comes from erroneous heuristic-based thinking. They found that humans undervalue outcomes that are merely probabilistic in comparison to results that are obtained with certainty, and that people generally disregard components that are shared by all prospects under consideration. According to the Prospect Theory, value is assigned to gains and losses rather than to final assets.

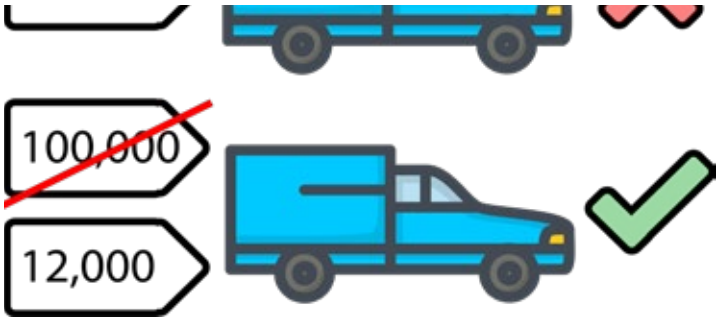
These are some of the heuristics proposed by Kahneman:

1 **Availability** denotes the ease with which a particular thought is brought to mind when evaluating a specific topic, concept, method or decision. The availability heuristic operates on the notion that if something can be recalled, it must be important, or at least more important than alternative solutions which are not as readily recalled. Under the availability heuristic, people tend to heavily weight their judgments toward more recent information, forming new opinions biased toward these latest news while neglecting older data.

2 **Representativeness** characterizes judgments about the probability of an event under uncertainty and is defined as the degree to which an event is similar in essential characteristics to its parent population. It reflects the salient features of the process by which it is generated. When people rely on representativeness to make judgments, they are likely to judge wrongly because the fact that something is more representative does not actually make it more likely.

3 **Anchoring** or focalism is a cognitive bias that describes the average person's tendency to rely too heavily on the first piece of information offered (anchor) when coming to conclusions. During decision-making, anchoring occurs when individuals use an initial piece of information to make subsequent judgments. Once an anchor is set, other judgments are made by adjusting away from that anchor, and there is a bias toward interpreting other information around the anchor.

One example: The initial price offered for a used car sets the standard for the rest of the negotiations. Prices lower than the initial price seem more reasonable even if they are still higher than the actual value of the car.



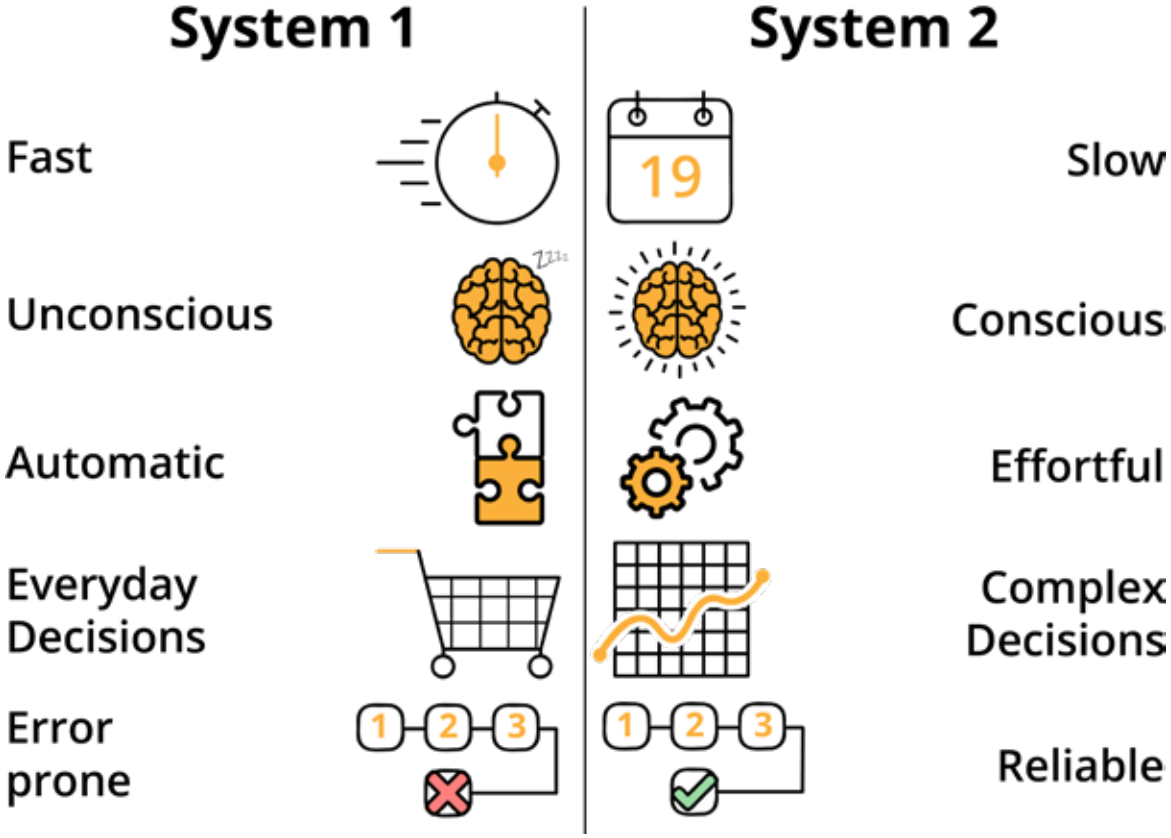
System 1 and System 2

Kahneman's theories were also concerned with how people process information. He proposed that there are two systems which determine how we make decisions: System 1 - which is fast but relatively inaccurate, and system 2 - which is slow but more accurate.

The theory suggests that our everyday decisions are carried out in one of these two ways, from buying our morning coffee, to making career choices. We will use different approaches depending on the circumstances.

We're more likely to use the slow, but reliable process of system 2 when making big decisions - we likely have more time, and can put more effort into the decision, and we're therefore more likely to get it right.

On the other hand, everyday and common decisions are more likely to engage our system 1 approach to thinking - it would slow us down too much if we had to consider all the variables of every type of coffee before deciding which one to buy. Our brain is therefore more likely to make a quick decision.



Daniel Kahneman - a researcher dedicated to human behavior

Daniel Kahneman is an Israeli-American psychologist notable for his work on the psychology of judgment and decision-making as well as behavioral economics, for which he was awarded the 2002 Nobel Memorial Prize in Economic Sciences.

His empirical findings challenge the assumption of human rationality prevailing in modern economic theory. With Amos Tversky and others, Kahneman established a cognitive basis for common human errors that arise from heuristics and biases.

In 2011, his book Thinking, Fast and Slow, which summarizes much of his research, was published and quickly became an international bestseller.

Decision-making and emotions

Human behavior and decision-making are heavily affected by emotions – even in subtle ways that we may not always recognize. After making an emotionally-fueled decision, we tend to continue to use the imperfect reasoning behind it, and "a mild incidental emotion in decision-making can live longer than the emotional experience itself" as pointed out by Andrade & Ariely (2009).

Fear or sadness affect decisions in a variety of ways. There have been many mood-manipulating studies on decision-making, including decisions made after getting a gift, decisions made after receiving unfair offers in negotiation, and the choice of college based on the weather at the campus visit.

An example of mood manipulation affecting decision-making was completed by researchers who wanted to know how a willingness to help could be affected by positive feelings.

To study their question, they placed a Quarter (25ct) clearly visible in a phone booth (yes, these things actually existed!) and waited for passers-by to find the coin. An actor working on behalf of the psychologist stepped in, asking to take an urgent phone call. Study participants who actually found the coin were significantly happier, allowing the confederate to take the call, while those who didn't find the coin were unaffected, and more likely to say no (Isen & Levin, 1972).

Various studies have concluded that not only does mood affect both simple and major decisions, but also that the impact of the mood induction on judgment could still be present one week later.

Ariely and Loewenstein (2005) showed that sexual arousal affects judgment when making sexual decisions – most participants were aware of this. However, the research team found that insight, judgment and self-control were overwhelmed by arousal in the heat of the moment, due to dramatic cognitive and motivational changes.

Conclusion

All of the above goes to show how we are emotional creatures, and that physiological arousal can determine how we ultimately act - what behaviors we carry out.

As our emotions and physiological states are hidden to us, they represent an important feature to investigate when considering people's behaviors. Kahneman has shown how decision-making is carried out by our subconscious. It therefore makes sense that if we want to understand decision-making, we need to find a way to investigate the conscious too.

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PART IV: Human behavior research

Getting started with human behavior research

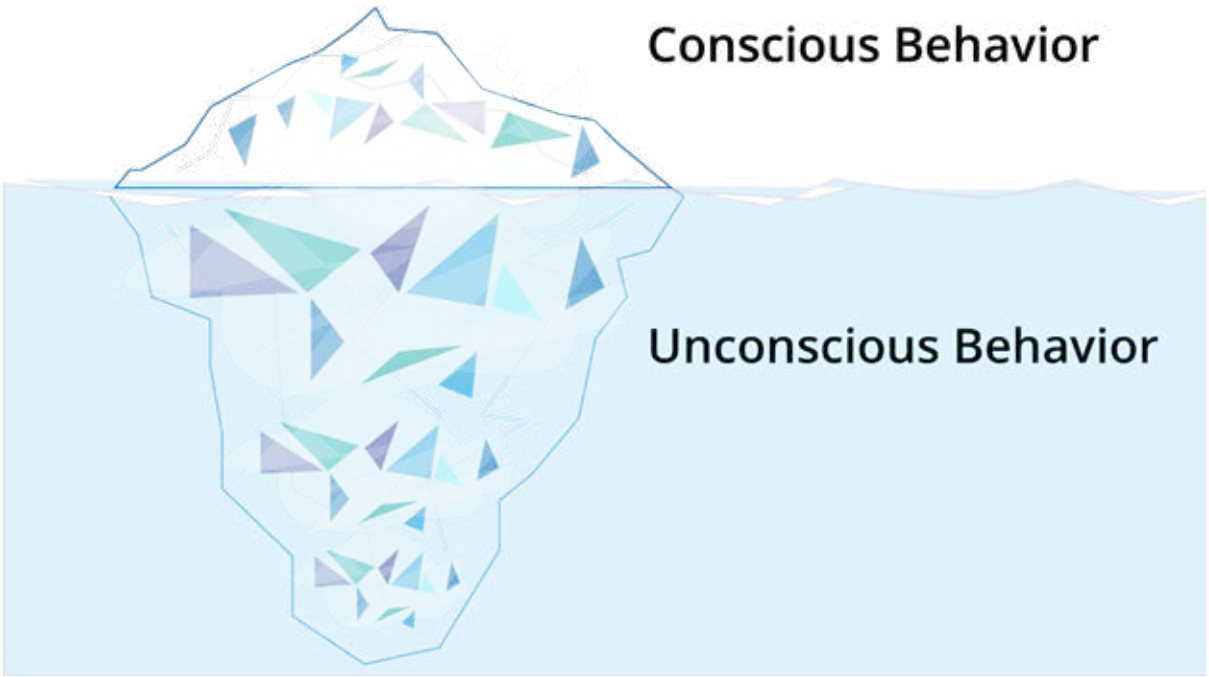
Research on human behavior addresses how and why people behave the way they do. However, as you have seen in the previous sections, human behavior is quite complex as it is influenced, modulated and shaped by multiple factors which are often unrecognized by the individual: Overt or covert, logical or illogical, voluntary or involuntary.

>> **Conscious vs. Subconscious behavior**

Consciousness is a state of awareness for internal thoughts and feelings, and allows for the proper perception and uptake of information from your surroundings.

In contrast, whenever you do things that are automated (or where you find yourself wondering "why did I just do that?"), your behavior might be completely out of conscious control. Interaction patterns can be subconscious as well as action sequences.

A huge amount of our behaviors are guided by subconscious processes. Just like an iceberg, there is a great amount of hidden information, and only some of it is visible with the naked eye.



Overt vs. covert behavior

Overt behavior describes any aspects of behavior that can be observed, for example body movements or (inter-)actions. Also, physiological processes such as blushing, facial expressions or pupil dilation might be subtle, but can still be observed. Covert processes are thoughts (cognition), feelings (emotion) or responses which are not easily seen. Subtle changes in bodily processes, for instance, are hidden to the observer's eye.

In this case, biometric or physiological sensors are used to aid the observation with quantitative measures as they uncover processes that are covert in the first place. Along this definition biometrics and other brain imaging methods all monitor physiological processes reflecting covert behavior.

Rational vs. irrational behavior

Rational behavior might be considered any action, emotion or cognition which is pertaining to, influenced or guided by reason. In contrast, irrational behavior describes actions that are not objectively logical.

Patients suffering from phobias often report an awareness for their thoughts and fears being irrational ("I know that the spider can't harm me") – albeit they still cannot resist the urge to behave in a certain way. In contrast, schizophrenic patients, who may exhibit sensory hallucinations, are typically not aware of the irrationality of their actions. They actually perceive objects or people in their environment which do not exist.

Voluntary vs. involuntary behavior

Voluntary actions are self-determined and driven by your desires and decisions. By contrast, involuntary actions describe any action made without intent or carried out despite an attempt to prevent it. In cognitive-behavioral psychotherapy, for example, patients are exposed to problematic scenarios, also referred to as flooding, such as spiders, social exhibition or a transatlantic plane ride.

Typically, phobic patients have acquired quite some behavioral repertoire helping them to avoid these problematic scenarios as they cause extreme physiological arousal and panic attacks. While the exposure might be completely involuntary, these sessions help overcome the panicking. As the situation cannot be evaded, bodily arousal diminishes, allowing patients to reflect the environment and regain control.

Conclusion

Many of our behaviors appear to be voluntary, rational, overt, and conscious - yet they only represent the tip of the iceberg for normal human behavior. The majority of our actions are involuntary, potentially irrational, and are guided by our subconscious. The way to access this other side of behavior is to examine the covert behaviors that occur as a result.

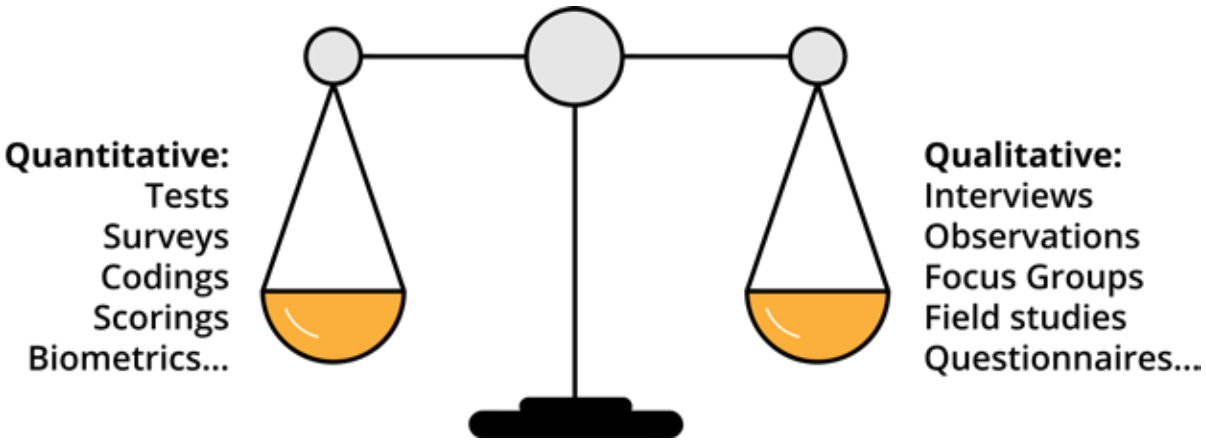
Measuring human behavior

In order to describe and interpret human behavior, academic and commercial researchers have developed intricate techniques allowing for the collection of data indicative of personality traits, cognitive-affective states and problem solving strategies.

Typically, insights are obtained based on empirical procedures, which means that scientists do not stick to thought experiments but collect data empirically by means of laboratory, field and natural experiments. In experimental setups, specific hypotheses about stimulus-response relationships can be clarified. Generally, research techniques employed by scientists can be classified into qualitative and quantitative procedures.

>> **Qualitative studies** gather non-numerical insights, for example by analyzing diary entries, using open questionnaires, unstructured interviews or observations. Qualitative field / usability studies, for example, aim towards understanding how respondents see the world and why they react in a specific way rather than counting responses and analyzing the data statistically.

>> **Quantitative studies** characterize statistical, mathematical or computational techniques using numbers to describe and classify human behavior. Examples for quantitative techniques include structured surveys, tests as well as observations with dedicated coding schemes. Also, physiological measurements from EEG, EMG, ECG, GSR and other sensors produce quantitative output, allowing researchers to translate behavioral observations into discrete numbers and statistical outputs.



Behavioral observation

Behavioral observation is one of the oldest tools for psychological research on human behavior. Researchers either visit people in their natural surroundings (field study) or invite individuals or groups to the laboratory.

>> **Observations in the field** have several benefits. Participants are typically more relaxed and less self-conscious when observed at home, at school or at the workplace. Everything is familiar to them, permitting relatively unfiltered observation of behavior which is embedded into the natural surroundings of the individual or group of interest.

However, there's always the risk of distraction - shouting neighbors or phones ringing. Field observations are an ideal starting point of any behavioral research study. Just sitting and watching people offers tremendous amounts of insights if you're able to focus on a specific question or aspect of behavior.

>> **Observation in the laboratory,** by contrast, allows much more experimental control. You can exclude any unwanted aspects and completely ban smart phones, control the room layout and make sure to have everything prepared for optimal recording conditions (correct lighting conditions, ensuring a quiet environment, and so on).

You can create near-realistic laboratory environments - building a typical family living room, office space or creative zone, for example, to make respondents feel at ease and facilitating more natural behavior.

Qualitative observation focuses on the description of the seen, with a strong focus on value-free documentation of subjective impressions of the individual respondent.

Quantitative observation allows experimental conditions to be compared, and conclusions from the data can be drawn. It contrasts to qualitative observation by providing a numerical representation of behavioral frequencies. How often did the respondent reach for an object? How often did they look into each other's eyes?

Surveys and questionnaires

Surveys and questionnaires are an excellent tool to capture self-reported behaviors and skills, mental or emotional states or personality profiles of your respondents. However, questionnaires are always just momentary snapshots and capture only certain aspects of a person's behavior, thoughts and emotions.

The underlying principle is that intrinsic factors that are hidden and subconscious to the respondent are driving the observable (and measurable) behavior. These hidden factors are generally classified into traits and states. A questionnaire that combines traits and states is the State-Trait Personality Inventory (STP) by Spielberger (1995).

Surveys and questionnaires typically measure what Kahneman would describe as system 2 processes - thoughts that are carried out slowly and deliberately. System 1 processes - thoughts that are fast and automatic - can be measured by other methods that detect quick physiological changes.

>> **Personality traits** are supposed to be stable across multiple situations. You might have encountered the Big Five Personality traits as described by Goldberg (1993): Openness to experience, conscientiousness, extraversion, aggreeableness and neuroticism. Other classification systems also exist, but the Big Five are considered standard canon for any research study on behavioral outcomes of personality traits.

>> **Physiological, emotional or mental states** are expected to vary dependent on the task situation at hand. You can have an aroused or joyful state, or be in states of increased attention or cognitive workload. States change across the day, across seasons, or life events.

Focus groups

In market research, focus groups typically consist of a small number of respondents (about 4–15) brought together with a moderator to focus on beliefs and attitudes towards a product, service, concept, advertisement, idea or packaging. Focus groups are qualitative tools as their goal is to discuss in the group instead of coming to individual conclusions.

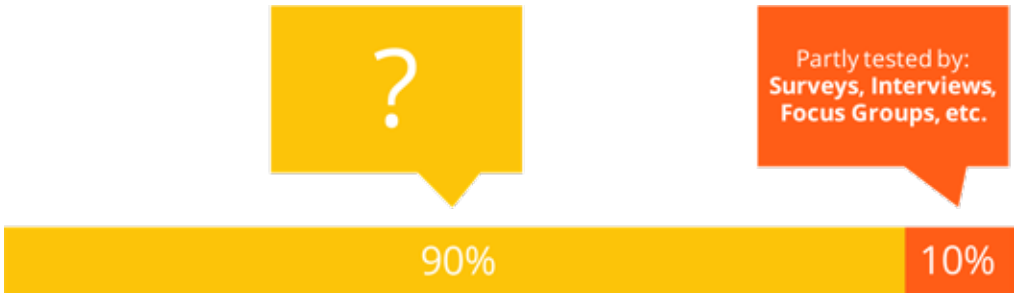
What are the benefits of a product, what are the drawbacks, where could it be optimized, who are ideal target populations? All of these questions can be addressed in a focus group. Individual preferences and beliefs are accumulated which may or may not represent those of the general population.

Beyond Surveys and Focus Groups

While surveys and focus groups can be instrumental in understanding our conscious thoughts and emotions, there is more to human behavior than meets the eye. The subconscious mind determines how our behavior is ultimately carried out, and only a small fraction of that is accessible from traditional methodologies - using surveys and focus groups.

As some researchers have claimed, up to 90% of our actions are guided by the subconscious. While the other 10% is important, it is clear that there is much to gain by probing further than what is tested by traditional methods.

Modern approaches aim to explore the hidden and uncharted territory of the subconscious, by measuring reliable outputs that provide deeper information about what someone is really thinking.



Biometric sensors

In addition to observing overt behavior, you can use biometric sensors and measurement devices in order to understand how mind, brain and body interact.

Biometrics give access to otherwise hidden processes. These usually hidden processes (at least to an observer) can give indications about the thought processes that Daniel Kahneman would describe as belonging to System 1 - fast and largely emotionally driven reactions. These reactions are quick processes that underlie a large portion of our decision-making and our resulting behavior.

>> **Eye tracking**

Eye tracking offers incredible insights into visual attention above and beyond any other experimental method. While eye tracking is commonly used to monitor where we direct our eye movements at a certain point in time, it also tracks the dilation of the pupil.

Changes in pupil dilation happen whenever the brightness of the stimulus material changes – when we step out of bright sunlight into a dark room, the pupils dilate to let in more light.

A similar dilation effect occurs when we're exposed to arousing stimuli or thoughts – the amount of dilation is proportional to the strength of arousal. As pupil dilation is an autonomic process, it cannot be controlled consciously. Thus, pupil dilation is an excellent method to assess immediate emotional arousal.

EEG

Electroencephalography is a neuroimaging technique measuring electrical activity generated by the brain from the scalp surface using sensors (electrodes) and amplifier systems. It is ideal for assessing brain activity associated with perception, cognition, and emotional processes.

Among all biosensors, EEG has the highest time resolution, thereby revealing substantial insights into sub-second brain dynamics of engagement, motivation, frustration, cognitive workload, and further metrics associated with stimulus processing, action preparation, and execution.

EEG impressively provides information about underlying brain processes while we perform a task or are exposed to certain stimuli. Unlike facial expression analysis, EEG is able to monitor the global emotional state of a person, which cannot be controlled consciously - you can fake your smile, but you can't trick your brain. Combining the two modalities allows you to get insights into both the moment-by-moment changes in emotional expression as well as variations in emotional states across a longer time span.

fNIRS

fNIRS (functional Near-Infrared Spectroscopy) records the diffusion of near-infrared light by human skull, scalp and brain tissue, allowing researchers to monitor cerebral blood flow in specified brain regions. While fNIRS is a relatively new technology, it has already proven to be a very promising tool in human behavior research.

fNIRS can, for example, be used to monitor cerebral blood flow in the frontal cortex as an indicator of cognitive workload (prefrontal activity) or motivation (prefrontal asymmetry). In the upcoming months and years, the applicability for fNIRS will further grow, allowing you to answer more research questions on human behavior and cognition.

fMRI

Whenever you would like to accomplish brain imaging with excellent spatial resolution, MRI (Magnetic Resonance Imaging) is the method of choice. MRI can be used to generate structural scans of high spatial precision, representing an accurate and highly precise 3D rendering of the respondent's brain.

For examining dynamic changes in the brain, functional MRI (fMRI) can be used. The scanner uses magnetic fields and radio frequencies to measure changes in oxygenated and deoxygenated blood flow in specific regions of the brain, that can then be related to cognitive processes.

Functional imaging can be particularly useful when used alongside EEG recordings. In this case, the spatial precision of the fMRI meets the temporal resolution of the EEG. Both combined allow for sub-second reconstructions of the underlying neural activity, that can be associated with cognitive and behavioral processes, which is not possible using each method on its own.

GSR/EDA

Electrodermal activity (EDA), also referred to as galvanic skin response (GSR), reflects the amount of sweat secretion from sweat glands in our skin. Increased sweating results in higher skin conductivity. When exposed to emotional stimulation, we "sweat emotionally" – particularly on our forehead, hands and feet. Just as pupil dilation, skin conductance is controlled subconsciously, therefore offering tremendous insights into the unfiltered, unbiased emotional arousal of a person.

GSR measurements can be done with lightweight and mobile sensors, which makes data acquisition very easy. In addition, automatic data analysis procedures extract key metrics on the fly, giving you immediate access to the underlying changes in emotional arousal.

Facial expressions

As facial expressions are tied to our inner emotions, and our emotions rule so much of our behavior, studying facial expressions gives an insight into the reasons for our actions.

If you are interested in whether or not respondents are truly expressing their positive attitude in observable behavior, you should always consider adding facial tracking and expression analysis to the list of biometric sensors for your next behavioral research study.

Facial expression analysis is a non-intrusive method that assesses head position and orientation, micro-expressions (such as lifting of the eyebrows or opening of the mouth) and global facial expressions of basic emotions (joy, anger, surprise, etc.) using a webcam placed in front of the respondent. Facial data is extremely helpful to validate metrics of engagement, workload or drowsiness.

EMG

Electromyographic sensors monitor the electric energy generated by bodily movements of the face, hands or fingers, etc. You can use EMG to monitor muscular responses to any type of stimulus material to extract even subtle activation patterns associated with consciously controlled hand/finger movements (startle reflex). Also, facial EMG can be used to track smiles and frowns in order to infer one's emotional valence.

ECG/PPG

>> Track heart rate, or pulse, from ECG electrodes or optical sensors (PPG) to get insights into respondents' physical state, anxiety and stress levels (arousal), and how changes in physiological state relate to their actions and decisions.

Conclusion

While biometric and imaging methods present unparalleled access into an individual's thoughts, feelings, and emotions, the best way to understand someone in entirety is to complement the measurements with more traditional methods, such as with surveys and focus groups.

By combining the measures, we're able to interpret both parts of what Kahneman described as System 1 and System 2 - both fast, emotionally driven decisions, as well as slow and deliberate decisions. Utilizing the insights offered by both routes of investigation gives a whole view of the thoughts and behaviors that an individual possesses.

The grid below summarizes the two methods in an overview, and shows how using both can answer a wide array of questions.

Human behavior metrics

Metrics are derived from observation or sensor data and reflect cognitive-affective processes underlying overt and covert actions. Typically, they are extracted using computer-based signal preprocessing techniques and statistics. In the following, we will describe the most important metrics in human behavior research.

>> Emotional valence

One of the most indicative aspects of emotional processing is your face. Facial expressions can be monitored either using facial electromyography (fEMG) sensors placed on certain facial muscles, or video-based facial expression analysis procedures. A very fine-tuned manual observation technique is the Facial Action Coding System (FACS) primarily designed by Paul Ekman. Trained coders, and sophisticated software, can evaluate the amount of activation of modular Action Units (AU), which represent very brief and subtle facial expressions lasting up to half a second.

Based on the sub-millisecond changes in muscular activation patterns or changes in global facial features (lifting an eyebrow, frowning, lifting up the corners of the mouth), behavioral researchers infer universal emotional states such as joy, anger, surprise, fear, contempt, disgust, sadness or confusion.

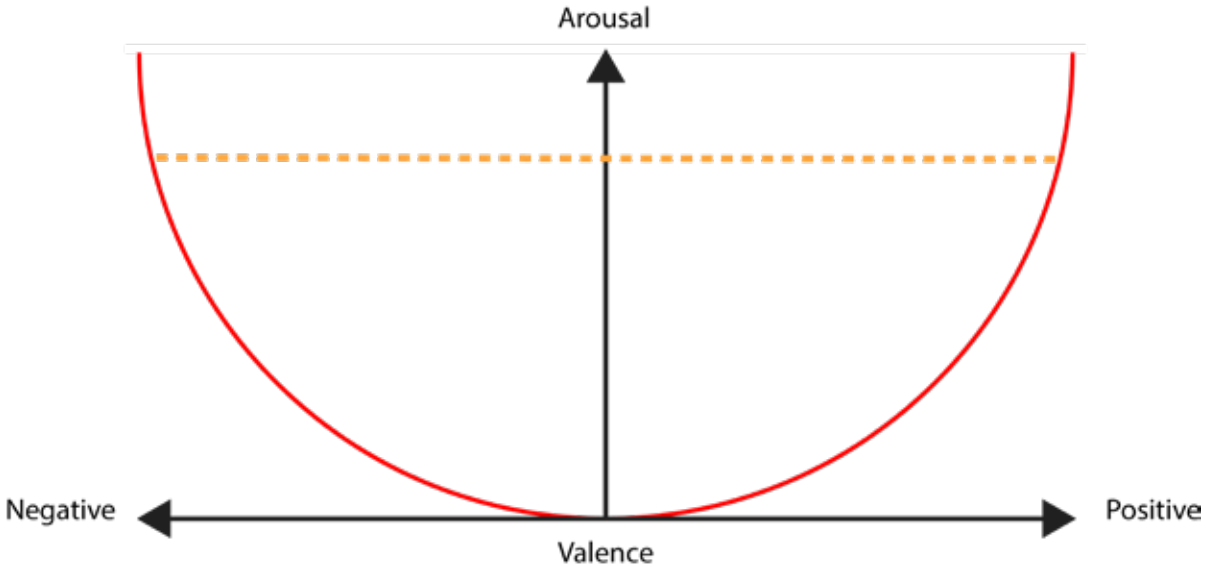
Emotions are associated with positive or negative connotations, also referred to as their valence. Analyzing when and where specific emotions occur can help improve products or services, or get insights into mental states and processing strategies of the individual.

>> Emotional arousal

While facial expressions can provide insights into the general direction of an emotional response (positive - negative), they cannot tell the intensity of the felt emotion as described by means of arousal. Arousal refers to the physiological and psychological state of being responsive to stimuli and is relevant for any kind of regulation of consciousness, attention and information processing.

The human arousal system is considered to comprise several different but heavily interconnected neural systems in the brainstem and cortex, responsible for emission of neurotransmitters such as acetylcholine, norepinephrine, dopamine, histamine and serotonin.

Physiological arousal and emotional valence can be thought of as taking place on a scale, in which both interact with each other. The intensity of arousal therefore influences the intensity of emotion. Capturing data about both of these processes can provide more information about an individual and their behavior.



Although all of these processes are taking place on the microscopic level and cannot be observed with the eye, arousal can be measured by using several psychophysiological methods such as eye tracking, EEG, GSR, ECG, respiration, and more.

For example, the amount of pupil dilation is related to physiological arousal. Similarly, the number of GSR peaks, and the amplitude of the peaks, indicates the level of arousal towards sensory stimuli or mental images.

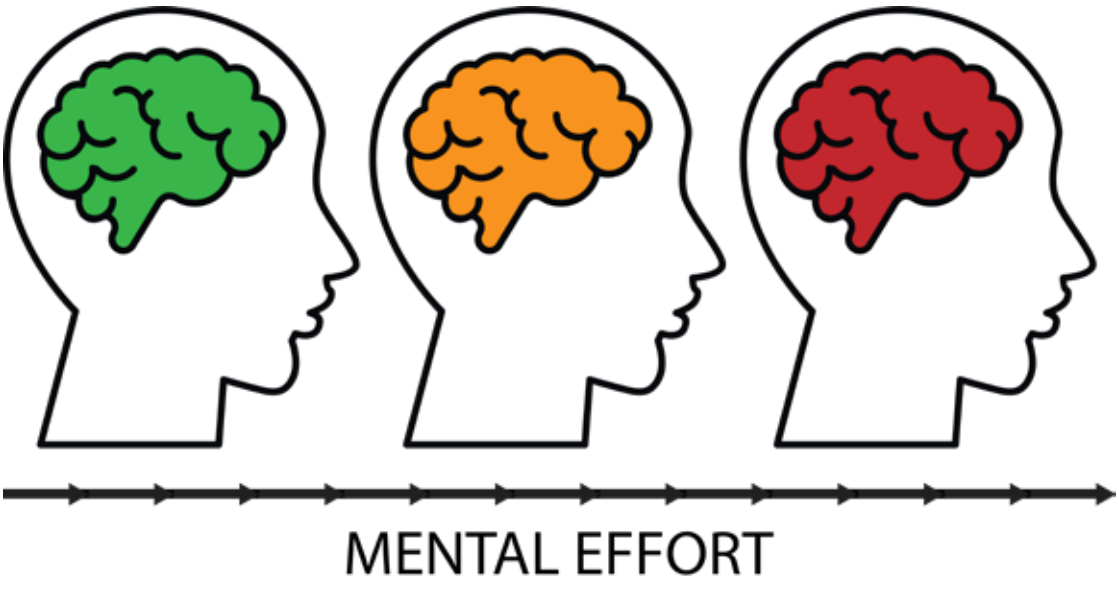
Importantly, arousal can be elicited both by positive and negative events. In other words, it is blind for the valence of a stimulus. A picture of an attacking snake might trigger the same amount of arousal as a picture of a happy family does. However, in the "snake" condition arousal might be associated with fear (negative arousal), whereas in the "family" condition arousal might be associated with happiness (positive arousal).

This is why metrics reflecting both arousal and valence have to be based on several physiological sensors, allowing you to triangulate and cross-validate your findings.

Workload and cognitive load

Decisions are often made under several constraints (with respect to time, space and resources), and there is obviously a threshold in how much information you can take into consideration. Working memory represents the cognitive system responsible for transient holding and processing of information, and human cognitive-behavioral research has a particular interest in this aspect due to its crucial role in the decision-making process.

The total amount of mental effort being used in working memory is typically referred to as cognitive load.



One way to measure cognitive load is with EEG, either individually or in conjunction with other biometric sensors. By measuring the electrical activity over medial frontal areas (the middle of your forehead) during a demanding task such as counting backwards from 101 in steps of 7, a time series of voltage amplitudes can be collected. The time-series can then be decomposed into the underlying frequencies (similar to a glass prism separating different frequencies of light into a rainbow).

Brain rhythms can provide indicators of working memory load, allowing researchers to observe when heavy processing of information is occurring. Besides EEG, eye tracking can also provide essential information on cognitive load by monitoring pupil dilation and eye blinks. In detail, cognitively demanding tasks are generally associated with widening of the pupil and delays in eye blinks.

Perception and attention

Do stimuli "pop out" and elicit our interest? Do we watch a movie clip or an advertisement because it is visually captivating? For cognitive-behavioral scientists it is highly relevant to determine the level of saliency of stimuli, and whether or not it captures our attention. Saliency detection is considered to be a key attentional mechanism that facilitates learning and survival. It enables us to focus our limited perceptual and cognitive resources on the most pertinent subset of the available sensory data.

Motivation and engagement

Another metric relevant for cognitive-behavioral scientists is motivation, sometimes referred to as action motivation. It describes the drive for approaching/avoiding actions, objects and stimuli.

Shopping behavior is primarily driven by engagement and the underlying motivation to buy a product, therefore it would be beneficial to infer one's motivation already during the initial exposure with an item. EEG experiments have provided rich evidence for certain brain activation patterns reflecting increased or decreased motivational states.

One of the most robust metrics for motivation is the so-called "prefrontal asymmetry", which describes the asymmetry between left and right brain hemispheres in the (8 - 12 Hz) alpha band. Combining EEG measures with self-reports revealed that prefrontal EEG asymmetry accounted for more than 25% of the variance in the self-report measure.

In more detail, respondents with greater relative left prefrontal activation reported higher levels of approaching behavior, whereas those with greater relative right prefrontal activation reported higher levels of avoidance.

Current EEG research addresses which features of a stimulus drive saliency, and how these features interact with our memory systems.

Besides EEG, one's level of attention can be determined based on eye tracking, both in lab settings as well as in real world environments. Remote eye trackers are mounted in front of a computer or TV screen and record the respondents' gaze position on screen. You can then replay the video and visualize the gaze trace as overlay.

This can also be done in an aggregated fashion across several respondents, resulting in heat maps which show the gaze distribution and indicate which locations on screen attracted most attention (focus of attention).

Eye tracking glasses are the optimal choice for monitoring attentional changes in freely moving subjects, allowing you to extract measures of attention in real world environments such as in-store shopping or package testing scenarios.

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PART V: Application fields

Consumer neuroscience and neuromarketing

There is no doubt about it: Evaluating consumer preferences and delivering persuasive communication are critical elements in marketing. While self-reports and questionnaires might be ideal tools to get insights into respondents' attitudes and awareness, they might be limited in capturing emotional responses unbiased by self-awareness and social desirability.

As only so much of our overt, conscious behavior is captured by traditional methods such as surveys and focus groups, biometric research offers a way to fill that gap. As stated previously, biometric methods are able to evaluate an individual's attention, emotions, cognition, and physiological arousal - providing a deeper insight into how someone attends to information.

Self-reports can be enriched using facial expression analysis in order to obtain quantified measures of more subconscious emotional responses towards a product or service. Based on facial expression analysis, products can be optimized, market segments can be assessed, and target audiences and personas can be identified.

Furthermore, GSR sensors can be used to extract physiological arousal when unboxing a package or walking along a storefront, allowing you to achieve a more detailed representation of cognitive-affective systems driving observable behavior compared to a single modality alone.

By using EEG and readily-calculated metrics, it's possible to define how engaging or deterring a product could be. Intercepting this information at a cognitive level can be extremely powerful.

Overall, the use of biometric methods with more traditional consumer research methods can provide a complete understanding of what does, and what doesn't, appeal to potential consumers.

Psychological research

Psychologists analyze how we respond emotionally towards external and internal stimuli, how we think about ourselves and others, and how we behave. In systematic studies, researchers can measure and vary stimulus properties (color, shape, duration of presentation) and social expectancies in order to evaluate how personality characteristics and individual learning histories impact emotional, cognitive and perceptual processing.

The use of biometrics has often emerged within, and through, psychology research - eye tracking and EEG are good examples of this. The methodology has therefore been continuously refined and implemented by researchers within this field. By taking this knowledge and combining a wide array of sensors within an experimental setting, psychological research can be accelerated, and more questions can be answered.

Media testing and advertising

In media research, individual respondents or focus groups can be exposed to TV advertisements, trailers and full-length pilots while monitoring their behavioral responses, for example, using facial expression analysis. Identifying scenes where emotional responses were expected but the audience just didn't "get it" is crucial to refining the appeal of the TV-program. Facial expression analysis can also be used to find the key frames that result in the most extreme facial expressions - showing when the program really landed on target.

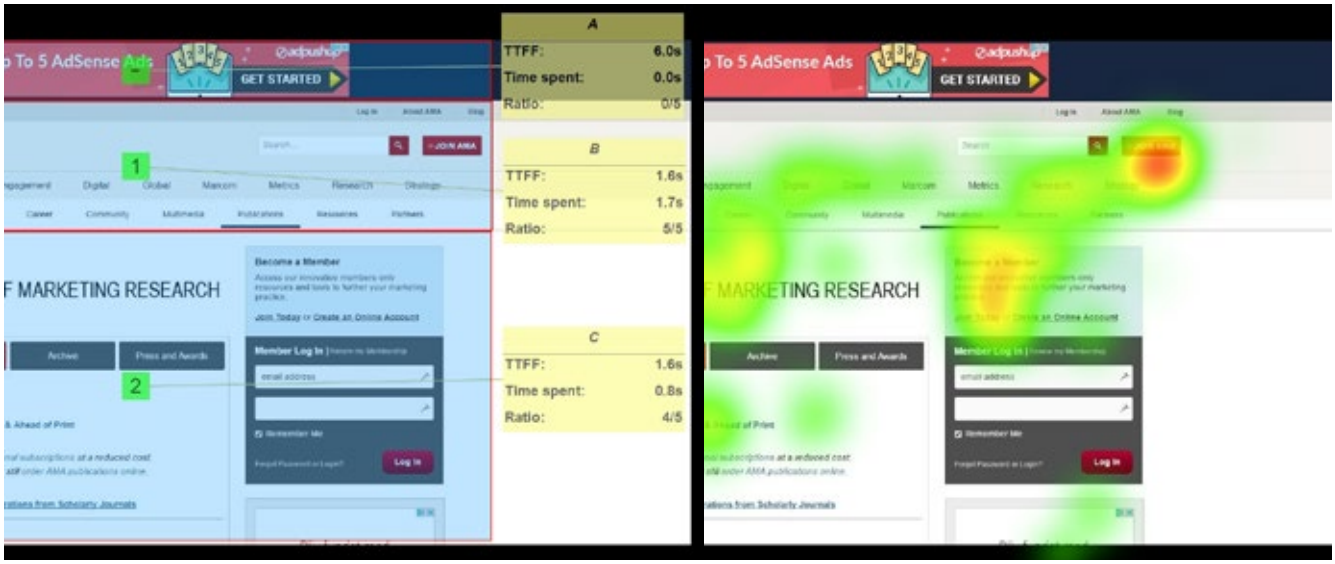
In this context, you might want to isolate and improve scenes that trigger unwanted negative expressions indicating elevated levels of disgust, frustration or confusion (those kind of emotions wouldn't exactly help a comedy show to become a hit series, would they?) or utilize your audience's response towards a screening in order to increase the overall level of positive expressions in the final release.

Biometric equipment is non-invasive and can be easily attached (or only requires a webcam), making it quickly implementable, and ideal for understanding viewer thoughts and behavior.

Software UI and website design

Ideally, handling software and navigating websites should be a pleasant experience - frustration and confusion levels should certainly be kept as low as possible. Monitoring user behavior, for example based on scrolling or click-ratio as well as facial expressions, while testers browse websites or software dialogs can provide insights into the emotional satisfaction of the desired target group.

Eye tracking is a particularly useful technology, as it helps pinpoint exactly what the person is looking at during their experience with the website. When combined with other measures, it gives an insight into what exactly gave them a positive or negative feeling during the interaction.



Whenever users encounter road blocks or get lost in complex sub-menus, you might certainly see longer navigation phases and increased negative facial expressions such as brow furrowing or frowning.

Difficulties that arise can be measured through EEG headsets, showing when the greatest levels of avoidance or engagement occur. GSR measurements are able to complement the use of facial expression analysis, providing information about the intensity of the emotion felt at certain points of website or software navigation.

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iMotions Biometric Research Platform

Human behavior research ... done right

Before you kick off your human behavior study, you certainly want to think about which recording and data analysis software to use. Usually, separate software is required for stimulus presentation and data recording.

What if there was a multimodal software solution that allows for presenting any type of stimuli while recording data from physiological sensors such as EEG, eye tracking, facial expression analysis, GSR, ECG, and EMG without having to piece everything together?

iMotions Biometric Research Platform

Motions Biometric Research Platform is one easy-to-use software solution for study design, multisensor calibration, data collection, and analysis.

Out of the box, iMotions supports over 50 leading biometric sensors including facial expression analysis, GSR, eye tracking, EEG, ECG, and EMG along with survey technologies for multimodal human behavior research. **Get in touch** with our team at iMotions to learn how we can help elevate your research!

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