# Chapter 1: Sources of the Placebo Effect

The context in which a stimulus is presented to us has an enormous influence on the way we perceive and react to that stimulus. Most people are either unaware of this fact or ignore it, as it introduces an uncomfortable element of doubt into their transactions with the world. If we question whether the expensive wine we drink actually tastes better, or if it merely tastes better because it is expensive, we may be forced to admit that all our perceptions are flawed, from the way we think our colleagues interpret what we say, to the way we remember pivotal moments in our personal histories. Therefore most of the time we accept our perceptions of both internally and externally generated events as being accurate and in some sense true. These flawed perceptions go on to guide both our volitional and non-volitional responses to the stimuli we encounter. One of the goals of psychology as a science is to explain the reasons for the gap between what we perceive as reality and what that reality actually is, and to use this knowledge to help develop ways to calibrate the two states so that individuals can base their future decisions on a view of the world undistorted by their beliefs, expectations, and predilections.

## Expectancies

Expectancies are important moderators of how we perceive and interact with the world and are central to influential theories in learning and in clinical, social, educational, and developmental psychology. Expectancies can be defined as schemas that are activated based on appraisals of the likelihood of a stimulus or response signaling the arrival of another stimulus (Bolles, 1972; Rescorla & Solomon, 1967). Thus the context preceding the occurrence of a stimulus can itself be considered a stimulus that gives us an indication of what to expect when the antecedent stimulus arrives. Here it may be necessary to define what is meant by a stimulus. In psychology a stimulus is any object or event that can be perceived by the organism. Thus stimuli can be external to the organism or they can be internally registered perceptions, thoughts or emotions. So long as they can be perceived they are stimuli (Eikelboom & Stewart, 1982).

Schemas are organized patterns of stored information acquired by observing the relations between all the stimuli the organism has experienced. They are derived via the classification of stimuli into classes based on salient features that individuals within each class share (DiMaggio, 1997). Thus completely novel stimuli can still elicit expectancies if these stimuli are judged to belong to a class with which the organism has prior experience. Expectancies are useful in that they provide us with a heuristic that allows us to efficiently assimilate novel information into our existing worldview. However they can also alter the way we perceive and respond to any stimuli that occur after the schema that generates the expectancies has been activated. A simpler definition of expectancies is that they are beliefs about what will happen when a particular stimulus occurs. No matter how expectancies are defined, most modern explanations for the placebo effect agree that it is a phenomena that arises as a result of expectancies.

## The Placebo Effect

The most archetypal example of a placebo effect is when an individual experiencing some form of pain is given an inert sugar pill under the guise of an analgesic and subsequently reports a reduction in pain. This canonical example, while instructive, does not adequately cover the scope of placebo effects. A more all-encompassing definition of a placebo effect is: any change on an outcome that is brought about by the administration of a pharmacologically inert compound or therapeutically inert treatment. It is widely thought that placebo effects are brought about by expectancies held by the individual receiving the placebo treatment concerning the consequences of that treatment (Montgomery & Kirsch, 1996); however as yet there are no definitive answers as to which mechanisms are responsible for the phenomenon.

When no active treatment has been administered a placebo treatment can lead to effects that mimic the effects of the active treatment (Hull & Bond, 1986; Kirsch & Weixel, 1988; Marlatt & Rohsenow, 1980). Furthermore even when an active treatment *has* been administered, awareness of having received the treatment and expectancies about the likely effects of receiving the treatment can elicit placebo effects that augment (Amanzio, Pollo, Maggi, & Benedetti, 2001; Benedetti, Maggi, et al., 2003; Neukirch & Colagiuri, 2015; Penick & Fisher, 1965; Penick & Hinkle, 1964) or inhibit (Aslaksen, Zwarg, Eilertsen, Gorecka, & Bjørkedal, 2015; Bingel et al., 2011; Flaten, Simonsen, & Olsen, 1999) the direct effects of the treatment itself. Because placebos are used widely in clinical trials to isolate the active effects of a treatment from the effect of expectancy, in medical settings the placebo effect has been considered a nuisance variable, a factor to be ‘controlled out’ in order to gauge the precise effects of the treatment alone. However new advances in placebo research suggest that patients’ expectancies of treatment effects, far from being a nuisance, can in fact be harnessed in order to enhance treatment outcomes.

Placebo effects have been observed for a wide range of psychophysiological phenomena, including analgesia (Amanzio & Benedetti, 1999), hyperalgesia (Benedetti, Amanzio, Casadio, Oliaro, & Maggi, 1997), improved motor function (Pollo et al., 2002), reduced insomnia/improved sleep (Neukirch & Colagiuri, 2015; Suetsugi, Mizuki, Yamamoto, Uchida, & Watanabe, 2007), bronchioconstriction (Butler & Steptoe, 1986) and immunosuppression (Longo et al., 1999). Placebo effects can be positive or negative, depending on what the patient is expecting from the treatment. Side-effects of a drug for example can be induced with placebo manipulations in much the same way as the desired effects (Colagiuri, McGuinness, Boakes, & Butow, 2012; Shapiro, Chassan, Morris, & Frick, 1974). Possibly the most salient example of an aversive placebo effect, or nocebo effect, is the anticipatory nausea experienced by patients undergoing chemotherapy (Montgomery & Bovbjerg, 2001, 2004; Roscoe, Hickok, & Morrow, 2000).

The type and direction of the placebo effect elicited by the expectancy that one has received a treatment depends largely on the particular expectancies held by the individual who receives the placebo concerning the likely outcome of the treatment. Expectancies can be acquired directly through personal experience with the treatment, either in the laboratory or *in vivo,* or indirectly through social learning or generalisation of stimuli.

## Expectancy vs Conditioning

That the placebo effect exists is universally agreed upon. However there is less agreement on precisely what mechanisms give rise to it. The following sections will examine the various theories concerning the psychological and physiological mechanisms behind placebo effects.

### Stimulus Substitution Model

The placebo effect is most often explained as a learning phenomena, specifically an example of classical conditioning. In classical or Pavlovian conditioning, when a neutral stimulus (conditioned stimulus or CS) is paired with a non-neutral stimulus (unconditioned stimulus or US) that reliably elicits a response (unconditioned response; UR), the neutral stimulus eventually acquires the ability to elicit the same or a similar response on its own in the absence of the US. This latter response to the solitary CS is known as the conditioned response (or CR). The archetypal example of classical conditioning is Pavlov’s (1927) famous experiment using a dog, its food, and a bell. Pavlov observed that the sight and smell of food (US) caused the dog to salivate (UR). Pavlov rang a bell (CS) each time the food was presented to the animal and did this over repeated feedings. Eventually ringing the bell on its own came to induce salivation (CR). For a long while this learning phenomenon was explained using a stimulus substitution model. ‘Stimulus-substitution’ in the model’s name refers to the fact that the CS comes to stand in for or substitute for the US in its ability to elicit the response in question. In this model the essential process that allows the substitution—and hence the conditioned response—to take place is the contiguous pairing of the CS with the US.

Following Pavlov’s discovery research began in earnest to determine what other unconditioned stimuli could be substituted with neutral stimuli. For example Pavlov and others found that the salivation that that followed morphine injection could also be conditioned to neutral stimuli (Collins & Tatum, 1925; Crisler, 1928; Pavlov, 1927). Conditioned responses that mimic unconditioned responses have also been found for atropine-induced pupil dilation (Korol, Sletten, & Brown, 1966) and morphine-induced hyperthermia (Eikelboom & Stewart, 1979, 1981) and gastric secretion (Rush, Pearson, & Lang, 1970).

Wickramasekera (1980) adapted the stimulus-substitution model of classical conditioning to explain placebo effects. According to this model the placebo effect is a conditioned response: The treatment itself is the US, the cues surrounding the treatment’s administration such as the vehicle of administration (e.g. pill, injection) or more general environmental cues (e.g. the room the treatment is administered in and/or the doctor who administers the treatment) are the CS, and the acute effects of the treatment on the central nervous system the UR. Repeated contiguous pairings of the effects of the treatment (US) and the context surrounding its administration (CS) eventually lead to a conditioned response (CR) that is similar to the UR, which can be elicited following the presentation of the CS alone. The reason an inert pill administered for the first time can produce a conditioned analgesic response is that all the patient’s prior experience with analgesics constitute conditioning trials that are generalized to the new pill and are thus able to produce a conditioned response to a novel stimulus. Thus, through stimulus substitution, inert treatments such as saline injections or sugar pills are able to evoke conditioned responses that mimic the responses to the active treatment.

The stimulus-substitution model was the dominant theory used to explain classical conditioning from Pavlov’s experiment until the early 1970’s. Eventually however the theory began to fall out of favour. This happened for several reasons.

The first reason was that the stimulus-substitution model is a descriptive model; it makes no attempt to explain the mechanisms by which the phenomenon occurs. This is not a fault with the theory *per se.* Many scientific models, such as the early models of the solar system, are descriptive only. However any model of such an important and widely applicable *cognitive* phenomenon needed an explanatory component in order for it to be widely accepted.

Secondly the stimulus-substitution model frames classical conditioning as a form of low-level mechanical process, something akin to a reflex; with the implication being that it occurs unconsciously. This contradicts evidence that learning is mediated as much by conscious processes as by unconscious (for a review see Mitchell, De Houwer, & Lovibond, 2009). For example one study found that when respondents had incorrect beliefs about the contingencies between events, their responding was in line with these incorrect beliefs rather than actual contingencies (Parton & Denike, 1966). Another experiment found that that when attention and cognitive load were diverted away from conditioning trials (tone paired with shock) via a masking task it resulted in both diminished contingency knowledge AND reduced electrodermal conditioned responses (Dawson, 1970; Dawson & Biferno, 1973). If conditioning is in some way unconscious/automatic then we would expect it to be unaffected by tasks that divert conscious attention. If placebo effects are a learning phenomenon and learning is a conscious process then it is likely that placebo effects are more than just a reflex.

Thirdly stimulus-substitution models are unable to explain the fact that some conditioned drug responses are opposite in direction to the unconditioned response (Crowell, Hinson, & Siegel, 1981; Lang, Brown, Gershon, & Korol, 1966; Lê, Poulos, & Cappell, 1979; Siegel, 1975). In their review of the drug-conditioning literature Eikelboom and Stewart (1982) show that, far from being a rare-exception, conditioned responses that are opposite in direction to the unconditioned response are more common across a wide range of drugs and bodily systems (e.g. salivatory, thermoregulatory, gastrointestinal) than responses that mimic the unconditioned response. If the conditioned stimulus comes to replace the function of the unconditioned stimulus, as the stimulus-substitution model maintains, then it should always evoke the same response. This problem takes on an extra dimension in stimulus-substitution models of *placebo effects*, where rodents’ conditioned response to a drug and humans’ placebo response to the same drug can be in opposite directions. For example in experiments on rodents, pairing morphine with a CS results in conditioned hyperalgesia and pairing a CS with a tranquiliser produces conditioned hyperactivity (i.e. CSs that oppose their respective US; Krank, Hinson, & Siegel, 1981; Siegel, 1975, 1976, 1983) whereas in human subjects placebo morphine reduces pain (Amanzio & Benedetti, 1999; Atlas et al., 2012; Benedetti, Amanzio, Rosato, & Blanchard, 2011; Evans, 1974) and placebo tranquilisers decrease activity levels (Frankenhaeuser, Järpe, Svan, & Wrangsjö, 1963; Frankenhaeuser, Post, Hagdahl, & Wrangsjoe, 1964). These inconsistencies in conditioned responses across drugs and between species are not easy to reconcile with the stimulus substitution model as it stands.

Lastly the stimulus-substitution model’s analysis of the essential associative processes behind classical conditioning is contradicted by evidence. For example the stimulus-substitution model postulates *contiguity* ofCS-US pairing as the necessary process in conditioning. However new findings began to emerge in the late 60’s and early 70’s showing that contiguous CS + US pairings do not always lead to conditioning if, for example, prior to the CS + US pairing, the CS occurred many times in the absence of the US (Rescorla, 1968). Thus while contiguity is the most common predictor of association formation it is by no means necessary.

The inability of the stimulus substitution model to provide an explanatory model of conditioning, or to adequately account for seemingly contradictory evidence, meant that a new theory of classical conditioning was needed.

### Revised Stimulus Substitution Model

Eikelboom and Stewart (1982) proposed a revision of the stimulus substitution model that addressed the apparent inconsistencies in the direction of conditioned responses. They proposed that conditioned responses to drugs *do* in fact always resemble the unconditioned response, but that the unconditioned response is not always the *observed* response. They hypothesised that if a drug acts on the afferent arm of the system in question (e.g. thermoregulatory, salivatory) then the observed drug effect will be the UR and the conditioned drug effect will be in the direction of the observed effect. If on the other hand the drug in question acts on the efferent arm of the system then the observed effect is actually the US not the UR, and will evoke a compensatory UR that is in the opposite direction to the observed effect. Thus situations where the conditioned response seems to oppose the unconditioned response are really just the result of incorrect identification of the US. This model seemed to address the inconsistencies between theory and evidence in the existing stimulus substitution model and is still generally well accepted. However there was still a problem for the stimulus-substitution model of *placebo effects.* The revised model now explained the inconsistencies in the evidence for conditioned responses in rodents, but offered no explanation for the contradictory evidence from human studies, where placebo responses most commonly act in the direction of the unconditioned stimulus. The inconsistency in the direction of the conditioned response to these drugs across species means either that: (1) the revised stimulus substitution model of classical conditioning is true for rodents and humans but that the drugs in question act on different arms of the systems involved in different species, or (2) that placebo effects in humans do not involve classical conditioning as it was then conceptualised. The contradictory findings clearly demanded a new theory to explain placebo effects.

### Expectancy Models

The need for a model of classical conditioning that was explanatory as well as descriptive and that took account of conscious learning led to researchers in the late 1960’s and early 1970’s to begin proposing theories of learning and classical conditioning that focused on the role of cognition and information processing. These theories framed classical conditioning as the learning of relations between events rather than a reflexive response to the repeated co-occurrence of stimuli. According to these models, conditioning is dependent not on contiguity but on the formation of expectancies, which are beliefs based on the perceived likelihood of one set of stimuli being followed or accompanied by another (Bolles, 1972; Rescorla & Wagner, 1972). The extent to which a CS is able to produce a conditioned response depends on the information the CS provides about the likelihood of the arrival of the US and subsequent UR (Rescorla, 1988). In expectancy models of classical conditioning both the UR and, eventually, the CR, are *preparatory* responses, the organism’s reaction to the anticipated arrival of the US. Viewed in this context, the bell that caused Pavlov’s dog to salivate—the same bell that in the past had accompanied the delivery of food—over repeated feedings became a predictive cue signaling that the food was about to arrive. The salivation that occurred when the bell was rung was therefore its body’s reflexive preparation for receiving that food. Thus the bell provides information that food is likely to soon be consumed, just as seeing the food or smelling the food would, and produces the same anticipatory salivation response. In the expectancy model of classical conditioning, while the conditioned *response* is still reflexive, the *learning* that leads to it is not, but is instead the product of observation, generalisation and an appraisal of likelihoods. In this model conditioning is no longer opaque, but is instead dependent on the processing of information.

Just as with the stimulus-substitution model before it, the expectancy model of classical conditioning was adapted to form the basis of a model of placebo effects. The Expectancy model of placebo effects attempted to explain the mechanisms behind placebo effects, by which expectancy alone can cause changes in psychophysiological states. According to the expectancy model, placebo effects result from the activation of *response expectancies* (Kirsch, 1999)*.* Response expectancies are defined as “the anticipation of nonvolitional responses” (Montgomery & Kirsch, 1997, p. 108). These are to be distinguished from the *stimulus* expectancies that are the focus of information theories of classical conditioning. Stimulus expectancies are the anticipation of external consequences such as food, money, praise, and punishment. Expectancies of nonvolitional responses are also distinct from expectancies of *voluntary* responses, which are more like intentions.

Similarly to the revised stimulus substitution model of classical conditioning, Expectancy theories of placebo effects suggest that for a stimulus to act as a US, and thus be able to be associated with a CS, it must be perceived. Therefore the drug itself cannot be a US, only the body’s response to it—the *effects of the drug*—can be, for it is only this response that can be perceived by the organism to whom the drug is administered. What the organisms who ingests a drug learns is that the drug makes it feel a certain way: analgesics produce pain relief, alcohol produces disinhibition, amphetamines produce arousal and so on. Therefore, for the organism being conditioned, the *response* to the active effects of the drug on the central nervous system acts as the unconditioned stimuli with which neutral cues are paired and which the expectancies of a nonvolitional response form around. Thus in a sense, according to expectancy theories of placebo effects, placebo effects are anticipatory responses to URs masquerading as USs and the reason why drug-oppositional placebo effects are not as common in humans is because tolerance develops without our perceiving it, and thus we form no expectations around it.

According to expectancy theorists such as Kirsch, classical conditioning is only one way that we come to acquire response expectancies. Other ways are through third party accounts such as reading or watching television, or through direct observation of others’ reactions to stimuli.

Both Kirsch’s account of placebo effects and Rescorla’s account of classical conditioning: a) emphasise *what* is learned and the *strength* of what is learned over the *source* of that learning; b) say that what is learned is the relationship between the *observed* effect and the CS.

The reason why an expectancy model of placebo effects was necessary was to explain the repeated findings that placebo responses are in the same direction as the observed effects of the active treatments they are disguised as, that is to say, in the same direction as the expected reaction. By talking of response expectancies Kirsch was attempting to separate expectancy effects from conditioning effects. Doing so allowed him to propose that conditioned responses and expectancy effects behave in an independent fashion. Thus, he says “when conditioning produces effects that are contrary to people’s expectancies, the effect of expectancy may be powerful enough to reverse the conditioning effect.” (Kirsch, 1999, p 172). Thus cf. the reason why human placebo effects seem to differ from animals’ conditioning effects is that the effect of expectancy reverses or counteracts the effect of conditioning. Whether this happens in an additive, multiplicative, or non-linear fashion Kirsch himself is unclear.

There are several strands of evidence to back up the theory that expectancies and conditioning are separate processes.

The first is that responses to placebos are often unrelated to the actual drug’s effects. For example while caffeine tends to improve motor performance, if participants expectancies are manipulated by experimenters so that they expect caffeine to impair their performance then their performance is impaired irrespective of whether they are given caffeine or placebo (Fillmore & Vogel-Sprott, 1992). The same holds if they are told to expect improved performance.

The second is that conditioning can be blocked by providing verbal information. For example Montgomery and Kirsch (1997) found that the placebo effects attributed to a topical analgesic cream but really brought about by a surreptitious shock reduction conditioning procedure (see Voudouris, Peck, & Coleman, 1985) could be eliminated if participants were told that the pain reduction they experienced was brought about by actual shock-level reduction.

The third is that placebo effects involving both instruction and conditioning are more pronounced than placebo responses that are elicited by either on their own (Amanzio & Benedetti, 1999). In general conditioning procedures seem to bring about stronger placebo effects than expectancy (Amanzio & Benedetti, 1999; Colloca et al., 2008; Voudouris et al., 1985), but Kirsch argues that while both conditioning procedures and verbal instruction generate expectancies, direct experience with the effects of a treatment (i.e. conditioning trials) generate stronger expectancies—and hence expectancy effects—than the mere assertions of a third party.

The last is that placebo effects can be resistant to extinction. Montgomery and Kirsch (1997) found that placebo analgesia increased rather than decreased across extinction trials. According to conditioning theory, conditioned responses should extinguish eventually if repeatedly unaccompanied by unconditioned stimuli. Therefore if placebo effects are caused by conditioning they should extinguish over time. The results of Montgomery and Kirsch’s (1997) study on the other hand would seem to suggest that placebo effects caused by expectancy are self-sustaining—because the expectancy itself produces a response that further reinforces the expectancy. On the whole however the evidence is mixed, with some studies confirming the resistance of expectancy effects to extinction (Boissel, Philippon, Gauthier, Schbath, & Destors, 1986; Traut & Passarelli, 1957) but more recent studies finding that placebo effects extinguish in the absence of direct reinforcement (Colloca, Petrovic, Wager, Ingvar, & Benedetti, 2010; Yeung, Colagiuri, Lovibond, & Colloca, 2014).

According to Kirsch it is clear that expectancy effects behave in a way that is different from conditioning. The problem is that in hypothesizing a separate phenomenon, it is also necessary provide a separate mechanism to explain *how* this phenomenon occurs. Kirsch does this via his ‘immediacy hypothesis’. He acknowledges that some expectancy effects may be mediated by other variables (e.g. trust, faith, hope, anxiety reduction, endorphin release, the therapeutic relationship); however he suggests that these variables cannot account for the full range of expectancy effects, and that some therefore some expectancies must affect the responses they anticipate in an *immediate* way, that is, directly and unmediated by other variables. So expectancies of pain-relief produce the changes in the nervous system that reduce pain, expectancies of alcohol ingestion produce arousal and so on. His principle evidence for this immediacy is from Montgomery and Kirsch (1996), where applying a placebo cream presented as a site-specific topical analgesic produced analgesia in the area it was applied to but not to another site where the same painful stimuli had been applied but without the cream. According to Kirsch’s interpretation such a specific placebo response cannot be explained via any global mechanism, therefore the expectancy of pain in that site only must have produced analgesia *directly* on that site only. This he says rules out the hypothesis that placebo analgesia is mediated by a conditioned release of endogenous opiates (Benedetti, 1996). This result was replicated by Benedetti, Arduino, and Amanzio (1999) however whereas Montgomery and Kirsch interpreted their result as proof that placebo effects are unmediated by other variables, Benedetti et al. (1999) interpreted the same result as being caused by specific activation of opioids in the site of the placebo cream

Kirsch’s expectancy model of placebo effects is a compelling attempt to update models of placebo effects with modern thinking on classical conditioning and with current evidence on placebo effects. While there is general agreement that people’s beliefs and expectations *are* responsible for placebo effects there are several problems with the expectancy model that warrant further discussion.

Firstly Kirsch suggests that “the occurrence of a subjective experience may be an immediate consequence of its expectation.” (Kirsch, 1999, p. 179). This is more understandable with fear or depression or anxiety, where anticipation of panic may make one panicked, or anticipation of sadness might make one sad, and hence the expectation directly induce the emotion. However, as Kirsch himself acknowledges, it is harder to imagine how anticipation of nausea can *directly* make one nauseous (i.e. via a constriction of the stomach wall?), or how anticipation of pain relief might *directly* relieve pain (i.e. reversing tissue damage?). Furthermore the site-specific placebo analgesia observed in Montgomery and Kirsch (1997) that is the cornerstone of his evidence for immediacy could just as easily be explained by response- or perceptual-shift or demand characteristics as by immediate and direct topical analgesia.

Secondly Kirsch does not identify a neurological, neurochemical or physiological mechanism that may be responsible for the implementation of these unmediated effects. In place of a mechanism he offers evidence for the immediacy hypothesis in findings showing that placebos have produced physiological changes, such as bronchioconstriction in response to instruction about placebo asthma medication (Butler & Steptoe, 1986), penile tumescence in response to placebo alcohol (Briddell & Wilson, 1976), and blood pressure and heart rate in response to instruction about receiving caffeine (Kirsch & Rosadino, 1993; Kirsch & Weixel, 1988). However penile tumescence, asthma attacks (Lehrer, Isenberg, & Hochron, 1993), heart rate, and blood pressure are all physiological symptoms that can be brought about by changes in subjective state, making Kirsch’s citing of them as evidence that placebo effects are unmediated by psychological variables seems misplaced. Kirsch also cites examples where tumours (Klopfer, 1957) and skin rashes (Ikemi & Nakagawa, 1962) were altered by information alone, but concedes that neither of those findings were replicated.

Thirdly the expectancy model is still unable to explain the dissociation between the direction of conditioned responses in animals and placebo responses in humans. Kirsch explains this anomaly as follows: “Thus when conditioning produces effects that are contrary to people’s expectancies, the effect of expectancy may be powerful enough to reverse the conditioning effect.” (Kirsch, 1999, p. 172). However this assertion would seem to imply either that rats do not experience expectancies or that their expectancy response is attenuated and thus results in an observed ‘expectancy + conditioning’ *net* response to drugs that is opposite to humans’. The holding of expectancies is not predicated on language or abstract reasoning. All it implies is that the organism is able to learn the relations between events and hold beliefs about the predictive value of CSs. Even behaviourists would be unwilling to assert these days that rats’ learning is *entirely* unconscious.

Lastly it is not immediately clear what response expectancies contribute to our understanding over and above stimulus expectancies. In expectancy theory the CR is a preparatory response, preparing the organism for the arrival of the US. In the expectancy theory of *placebos*, the CR is a preparatory response in anticipation of the *effects* of the drug, which are themselves a response to the active drug’s effects on the central nervous system. So as mentioned in Kirsch’s schema the conditioned placebo response is to a UR masquerading as a US. However Kirsch does not specify what the conditioned response to that response consists of. Without specifying what the CR consists of, the expectancy theory of placebo effects no longer resembles the expectancy theories of classical conditioning upon which it is based.

The expectancy theory of placebo effects was an attempt to reconcile contradictions in the placebo and conditioning literature, specifically the ability of humans to show placebo effects to novel stimuli based on instruction only and with no prior conditioning. Whether it achieved its goal is questionable. However the term expectancy has showed some utility as a euphemism for these unconditioned, instruction-only placebo effects.

### Expectancy vs Conditioning: Need there be a debate?

While there has been much debate about whether learning generally and placebo effects specifically are due to expectancy or conditioning, as Stewart-Williams and Podd (2004) point out, there is no reason why these two explanations of the placebo effect need be mutually exclusive. According to their model, both subjective and physiological placebo effects can be caused by instruction, classical conditioning, or a combination of both. The difference between the two is that classically-conditioned placebo effects can be mediated either consciously or unconsciously whereas placebo effects induced by instruction only *must* be mediated consciously. The evidence is largely consistent with this integrative model. Another integrative model is proposed by Benedetti et al. (2003) who propose that unsconsious physiological functions are affected more by conditioning, whereas if the effects of the treatment can be perceived consciously, expectancies play a greater role.

### Placebo Effects Induced by Instruction Only

According to Stewart-Williams and Podd’s model placebo effects induced by verbal manipulations only *must* be consciously mediated. Placebo effects brought about by instruction tend to be less pronounced than those brought about by conditioning (Amanzio & Benedetti, 1999); however instruction-only manipulations can often produce the most interesting findings, where placebo and nocebo responses can be induced by the same inert substance with different accompanying instructions, or where instruction can override the reported effects of an active drug. Butler and Steptoe (1986) found that the same placebo inhaler could either induce or prevent bronchioconstriction in asthmatics, depending on which outcome researchers led participants to expect via verbal instruction. Flaten (1988) similarly found that the lactose powder led to either sedation or arousal depending on the instructions given to participants. His laboratory also found that patients who were given a muscle relaxant but who were told it was a stimulant reported greater muscle tension than those who were truthfully told it was a muscle relaxant (Flaten, 1999). One multi-centre placebo-controlled trial testing the effects of aspirin on unstable angina listed “gastrointestinal irritation” as a possible side-effect in the information statements supplied by 2 of the 3 centres but not in the third. Patients at the former centres reported significantly higher rates of gastrointestinal problems than those at the latter, and were 6 times more likely to drop out of the study due to gastrointestinal distress (Myers, Cairns, & Singer, 1987). Fillmore and Vogel-Sprott (1992) found that participants who were informed that caffeine improved motor performance demonstrated a greater improvement in performance following administration of a caffeine placebo than participants who were told caffeine would impair performance. The examples above suggest that some placebo and nocebo responses to drugs appear to be entirely mediated by conscious verbal expectancies, occurring in the absence of any prior pairings of the drug with its effects. Furthermore when subjects are told that there is a possibility that they will receive a placebo the placebo response is lessened or eliminated (Kirsch & Weixel, 1988). These results appear to show that a verbal manipulation, even without prior pairings of a vehicle to a treatment or drug, can lead to a placebo response.

As mentioned earlier expectancies are derived from the information an organism receives about the contingency between events. Many animals possess the ability to generalise the information gained from one set of CS-US associations to a new set. This allows them to generate expectancies about the imminent arrival of a familiar US, based on the perceived similarity of certain features of a novel CS to a familiar CS that had reliably signalled the US in the past. Humans however are unique in that we are able to generate these expectancies not based solely on the physical and/or environmental features of the new CS, but on verbal information alone. Humans are unusual in that we have the ability, mainly through language, to abstract information (i.e. isolate salient features of particular instances from their specific context in order to form generalisations). Thus expectancies can be induced verbally in the absence of direct experience with a contingency between events (unlike in non-literate animals for whom contingencies can only be obtained through direct observation of events). Humans are unusual in that we have the ability, mainly through language, to abstract information (i.e. isolate salient features of particular instances from their specific context in order to form generalisations)

This abstract information can serve as a cue, an abstract cue, which can elicit placebo responses not possible in creatures who do not have language.

Thus merely by providing credible information about the likely effects of a drug to participants it is possible to have:

1. a conditioned response being elicited by a novel stimulus

e.g. analgesia can be caused by a placebo masquerading as a new treatment

b) a novel response (though the response itself can never be novel) being elicited by a familiar stimulus. For example omitting gastrointentinal irritation as a side effect on boxes containing aspirin in one group of participants led to significantly decreased reports of gastrointestinal complaints compared to a who received identical aspirin except packaged in boxes where the side effect was listed (Myers, Cairns and Singer, 1987).

c) The same inert substance leading to opposing effects. For example inert lactose pill causes sedation or arousal depending on what participants are told it was (Flaten, 1998).

Because we are able to abstract information from language we are able to produce conditioned responses in the absence of direct observation of a contingency between events. In other words, by **decontextualising** a previously acquired contingency between a drug and its unconditioned response and then **superimposing** that contingency onto a new drug we are able to produce what amounts to a conditioned response to a novel stimulus.

For verbal information alone to be able to induce conditioned responses participants must: a) be previously unaware that the effects in question are associated with the drug or treatment they think they are about to receive; b) believe that the experimenter is a credible source of information about the likely effects of the drug and that the vehicle they are given actually contains an active agent.

For example participants with food allergies who were told that a saline injection was an allergen developed allergic symptoms (Jewett, Fein, & Greenberg, 1990). Luparello, Lyons, Bleecker and McFadden (1969) gave asthmatic patients nebulised saline to inhale and told them it was an allergen. Approximately half of all participants developed dyspnea, decreased vital capacity, and increased airway resistance.

Arguably these purely verbally induced expectancies still rely, for their ability to induce placebo effects, on some familiarity with the physical or psychological symptoms that experimenters suggest will follow administration of that drug. Thus even verbally induced expectancies may be mediated to some extent by prior conditioning. ???????? reference

### Placebo Effects without Awareness

There is evidence that classical conditioning can occur without awareness in humans (Esteves, Parra, Dimberg, & Öhman, 1994; Öhman & Soares, 1994; Soares & Öhman, 1993a, 1993b; Wong, Shevrin, & Williams, 1994). Similarly there are examples of placebo effects that occur in the absence of awareness. For example Benedetti et al. (1998) were able to induce a placebo respiratory depression response following conditioning with buprenorphine (a partial opiate agonist) that, though objectively measurable, was unnoticed by participants and which had not been mentioned as a consequence of the administration of the drug. The control group, who had not received any prior pairings of the active drug with the placebo pill, showed no such respiratory depression. Since conditioning was achieved without awareness this result would seem to indicate a completely unconsciously mediated placebo response. Another study found that an immune-activation response could be conditioned to a neutral taste stimulus in human participants (Longo et al., 1999). Because the immune-suppression response produced no changes in physical or psychological symptoms that could be perceived by the subjects, this finding could truly be called a conditioned placebo effect without awareness. In another experiment Benedetti et al. (2003) injected participants with sumatriptan, a drug that increases human growth hormone levels, during pre-test training. On test a saline injection caused an increase in growth hormone levels. Once again the changes in growth-hormone levels both during training and test were unable to be detected by participants, indicating a nonconscious conditioning effect.

### Effect of Expectancy vs Effect of Conditioning

Often the effects of conditioning and expectancy do not operate in the same direction. As mentioned above the CR to morphine conditioning in rodents is hyperalgesia whereas in humans it is analgesia. Stewart-Williams and Podd (2004) suggest that this contradiction can be resolved by considering the types of learning involved. Conditioned compensatory responses can take place only when the learning is of the non-conscious, reflexive sort, whereas if learning is more declarative and consciously mediated—either through conditioning or instruction or both—then the conditioned response to placebo will always operate in the same direction as the unconditioned.

It is difficult to assess the independent contribution of expectancy and conditioning to placebo effects. This is because most conditioning procedures, through the organism perceiving the effects of the treatment, result in the formation of conscious expectancies. In general however it is thought that instruction on its own leads to weaker expectancies than expectancies obtained through direct experience, where it is likely that expectancy and contribute additively to the final response. In a meta-analysis Vase, Riley, and Price (2002) compared effect sizes of placebo analgesia from studies that used conditioning-only procedures to those that used instruction only. They found that conditioning-only procedures produced effect sizes of 0.85 whereas studies that used instruction yielded 0.83. Thus the placebo effects from the two different methods seem to produce similar sized placebo effects. However the only study included in their analysis that used a conditioning-only procedure was Amanzio & Benedetti (1999), compared to fourteen studies that used instruction-only procedures. Though Amanzio and Benedetti did have two conditioning-only procedures with adequate sample sizes, it seems difficult to make a reliable comparison of the difference between methods when so few conditioning-only studies were used. Furthermore in Amanzio and Benedetti (1999) the ‘conditioning-only’ group were merely told their saline injection on the test day was an inert antibiotic. The training days where they were given morphine that constituted their conditioning trials would have led to the development of expectancies during these trials due to their perception of the effects of the drug. Even if the researchers effectively removed expectancy on test day via their instruction they could not retroactively erase the expectancies that developed during training. Thus to what extent *any* drug whose effects are perceptible can be conditioned in the absence of expectancy is doubtful.

Indirect evidence that conditioning leads to stronger placebo effects than instruction comes from crossover designs. In a training phase Laksa and Sunshine (1973) gave participants an injection of either one of three doses of a synthetic opiate or placebo. This was followed by a second injection where all participants received a placebo. The level of analgesia was predicted by dose level of the first injection, with the group that received placebo during training showing the smallest level of analgesia throughout, though they did still experience a small analgesic effect in after both injections. Moulin et al. (1996) also used a crossover design to test the effect of morphine on chronic pain. Order of two injections, morphine and placebo, were counterbalanced across participants. The participants who received morphine first experienced effective analgesia with the second placebo injection. Interestingly the participants who received placebo first did not experience effective analgesia following either the first placebo injection *or* the subsequent morphine injection. These studies suggest that the reason why conditioning procedures produce stronger placebo effects is that they produce stronger expectancies. This interpretation is confirmed by Montgomery and Kirsch (1997) where the placebo analgesia in one group brought about by a surreptitious shock-reduction procedure were not present in another group who were told prior to the procedure that shocks were being reduced by experimenters, and thus not a result of the cream applied to their arm.

### Effect of Expectancy and Conditioning on Subjective vs Objective Outcomes

It has been demonstrated above that placebo effects for subjective outcomes can be influenced by instruction only and by conditioning only procedures, or both (see Amanzio & Benedetti, 2005). In the section on conditioning without awareness it was also shown that conditioning using hidden administration of drugs can induce placebo effects for a range of physiological symptoms. There is also evidence, discussed above, that instruction alone influenced objectively measurable symptoms such as bronchioconstriction (Luparello, Lyons, Bleecker, & McFadden, 1968), penile tumescence (Briddell et al., 1978), and blood pressure and heart rate (Kirsch & Weixel, 1988), however these are all physiological changes that can be heavily dependent on mindset and can occur in the absence of any drug. Expectancies derived from instruction only can also influence nonconscious *cognitive* processes such as implicit learning. Colagiuri, Livesey, and Harris (2011) asked participants to inhale a bubblegum odour while performing a contextual cueing task. Contextual cueing tasks are often cited as evidence for unconscious learning because reaction times on cued trials are consistently lower than to uncued trials despite participants being unable to consciously recognise the configurations in the cued trials. Participants were assigned to three different instructional sets: that the odour would improve their performance, that the odour would hinder their performance, or were given no instruction. Participants given positive instructions showed improved performance on the cueing task compared to the other conditions. Thus expectancy without conditioning was able to influence an unconsciously-mediated cognitive outcome in an analogous way to the unconsciously-mediated physiological outcomes already mentioned.

### Placebo Effects Induced by Both Expectancy and Conditioning

Expectancy and conditioning can act in isolation to produce placebo effects. However Stewart-Williams and Podd (2004) suggest that outside the laboratory most placebo effects will contain elements of both conditioning and expectancy. As long as the effects of the treatment are perceivable in some way by the recipient, most conditioning procedures will lead to a conscious awareness of the relationship between a treatment and its effects. That unconsciously conditioned responses to drugs can co-occur in conjunction with, but separate to, conscious expectancies is most obvious when conditioned responses and expectancies contradict one another. For example smelling a plastic rose or being shown a sealed jar filled with dust can induce asthma attacks in asthmatics (Dekker & Groen, 1956; Dekker, Pelser, & Groen, 1957; Luparello et al., 1968). The participants in these studies were aware that the stimuli could not cause an asthma attack—dust causes asthma but in a jar there is no way of inhaling it and a plastic rose contains no pollen—and thus should have had no expectation. It of suffering an attack, yet the visual resemblance to stimuli that had caused attacks in the past was enough to evoke an attack. A similar phenomenon is when long-abstinent heroin addicts suffer physical tolerance/withdrawal symptoms such as runny nose, goose-bumps and lachrymation upon merely witnessing the tools of heroin administration or another addict shooting up (Valliant, 1988). In both examples the sufferers are aware that they have not ingested the agent in question and thus do not have a conscious expectancy of a response, but nevertheless suffer a physiological reaction to the visual stimulus that they have come to associate with that agent.

There is general agreement that conditioning and verbal instruction lead to larger effect sizes than either on their own. In two similar experiments Voudouris et al. (1985) and Montgomery and Kirsch (1997) told participants that an inert cream was a powerful analgesic and would reduce the pain from a painful stimulus. There were three phases. In the pre-test phase participants were shocked with and without the cream at the same shock level. The placebo response was measured by subtracting pain ratings when the cream was not applied from pain ratings when the cream was not applied. In the training phase a conditioning procedure was applied whereby the shock level administered when the cream was applied was reduced surreptitiously but increased again when the cream was removed—thereby creating the illusion that the cream was reducing the pain. In the test phase the shock level during the trials when the cream was applied was increased to match that of shock levels without the cream and the difference between pain ratings with and without the cream calculated. Though placebo analgesia was higher following the conditioning procedure there was still a placebo effect in the first phase. This implies that both instruction only and conditioning with instruction can produce placebo effects, but that conditioning with instruction produces more pronounced placebo effects. Montgomery and Kirsch’s (1997) experiment differed from Voudouris et al.’s (1985) only in that during the test phase half the participants were told that the shock level had been reduced. The finding that placebo effects brought about by both conditioning and verbal suggestion are stronger than either alone has been well replicated (Amanzio & Benedetti, 1999; Benedetti, Durando, Giudetti, Pampallona, & Vighetti, 2015; Quinn, MacDougall, & Colagiuri, 2015).

In summary placebo effects can sometimes be induced without expectancy via hidden conditioning procedures, by expectancy only without conditioning procedures, or can incorporate elements of both. Generally placebo effects brought about by a conditioning procedures are more pronounced than those brought about by expectancy because most often conditioning procedures will result in the formation of expectancies. But, as Stewart-Williams and Podd (2004) contend, in the world beyond the laboratory it is likely that in most cases both conditioning and expectancy mediate placebo effects.

### Neurobiological Theories

Neurobiological theories pertain more to the neurological mechanisms that produce different forms of placebo effects. There are two predominant theories: those that suggest that the placebo effect acts via a neurochemical mimicry of the systems that produce the unconditioned effects of the drugs that are expected; and those that suggest that suggest placebo effects come about through the attention-mediated ‘gating’ of peripheral pain signals by higher brain areas.

*Neurochemical Mimicry*: The foremost researcher and theorist in this area is Fabrizio Benedetti and his colleagues, however the first major discovery that led to this theory was made by Levine, Gordon, & Fields (1978). In this seminal study, patients suffering from postoperative dental pain were given a placebo injection administered by intravenous catheter 3 hours after their operation. Then, 1 hour after the operation, the same participants were given a second injection of either placebo or the opiate antagonist naloxone. After the second injection the patients given naloxone’s pain ratings increased at a significantly higher rate than those given placebo, indicating that the placebo effect had been attenuated in those receiving the opiate antagonist. The authors concluded that the fact that a drug that blocks opiate receptors reduced placebo analgesia proves that placebo analgesia acts via the release of endogenous opioids in response to expectations of receiving pain relief. Other studies, by Benedetti and others, have replicated this result (Amanzio & Benedetti, 1999; Amanzio et al., 2001; Benedetti, 1996; Eippert, Bingel, et al., 2009; Grevert, Albert, & Goldstein, 1983).

Interestingly there are indications that subsystems other than the endogenous opioid system may be responsible for some placebo analgesic effects. Naloxone attenuates placebo effects brought about by expectancy or by conditioning with morphine or a combination of the two; however when conditioning is performed with non-steroidal anti-inflammatories it seems as if the endocannabanoid system is recruited for placebo pain-relief. This was shown in a series of influential studies by Benedetti and Colleagues. Amanzio and Benedetti (1999) found that the naloxone-induced blocking of placebo analgesia only occurred if conditioning procedures were performed with morphine. If conditioning was performed with the non-steroidal anti-inflammatory ketorolac naloxone was unable to fully block the placebo effect. This result was confirmed by Guo et al. (2010) who showed that naloxone blocked a morphine-conditioned increase in pain tolerance in mice, but failed to increase tolerance if the mice were conditioned with aspirin, another non-steroidal anti-inflammatory. These established that different systems and drugs could be responsible for placebo analgesia. That endocannabanoids were involved in non-opiate placebo analgesia was confirmed in a subsequent study by Benedetti, Amanzio, Rosato, & Blanchard (2011) who were able to effectively block ketorolac-conditioned analgesia with the cannabinoid antagonist rimonabant.

A different neurochemical has been identified as being involved in placebo *hyper*algesia: the peptide cholecystokinin or CCK. Benedetti et al. (1997) induced hyperalgesia by suggestion in postoperative pain patients. This was blocked by proglumide, the CCK antagonist, in a dose-dependent manner but not by Naloxone. It was hypothesised that since CCK is involved in anxiety mechanisms that perhaps proglumide prevented anticipatory anxiety and this is what prevented placebo hyperalgesia. This possibility was investigated further by Benedetti, Amanzio, Vighetti, & Asteggiano (2006). They found that a placebo administered with the suggestion of hyperalgesia induced both hyperalgesia and HPA-Axis activation, a measure of stress or anxiety. Both were blocked by benzodiazepam; however the CCK receptor antagonist proglumide blocked hyperalgesia but not HPA-Axis activation. This suggests that CCK is involved in the hyperalgesic but not the anxiety component of the nocebo effect and that proglumide does not abolish nocebo hyperalgesia by blocking anticipatory anxiety as previously hypothesized. Rather it interrupts a CCK-ergic between anxiety and pain. Therefore the anxiety is the catalyst that activates the downstream CCK-mediated nocebo hyperalgesia response. Thus if the anticipatory anxiety is blocked so too is the nocebo hyperalgesia; however if the downstream CCK is blocked only the hyperalgesia is affected but not the anxiety.

There is also evidence that placebo effects can operate on systems other than those responsible for pain and pain relief. Benedetti et al. (2003) were able to produce a placebo reduction in movement velocity in parkinsonian patients who had received implantation of electrodes for deep brain stimulation. When activated these electrodes facilitate ease of movement by stimulating the subthalamic nucleus. When switched off again the constriction of movement is reinstated. Participants had the electrodes turned off for a period in the presence of experimenters at four and two weeks prior to testing. On the test day participants had their velocity of movement measured while machines were left on but under three possible instruction conditions: no instruction, told that machines had been turned off, and told that intensity of stimulation had been increased to improve movement. The group given positive information showed no change compared to the no treatment group, but the group who were told their machines were turned off experienced a significant worsening in their motor performance. A related result in another study by Benedetti and colleagues (different colleagues) (2003) confirmed the effect of information on parkinsonian symptoms. Ten Parkinsonian patients with implants of electrodes in the subthalamic nucleus were stimulated covertly or overtly or had stimulation interrupted covertly or overtly. If patients were aware of the stimulation their motor performance improved faster than if they were unaware. Similarly if their stimulation was interrupted openly their motor performance deteriorated faster than if it was interrupted without their knowledge. Pollo et al. (2002) also found that Parkinsonian patients whose level of deep brain stimulation was titrated down and then up experienced slower deterioration and faster improvement of motor performance respectively when they were told to expect no change and then dramatic improvement than if they were told to expect deterioration and then slight improvement.

The proposed mechanism for the changes in Parkinsonian symptoms observed across these studies is the expectation-induced modulation of the dopaminergic system in the brain. Parkinson’s disease is known to be caused by loss of cortical dopamine levels (Brozoski, Brown, Rosvold, & Goldman, 1979; Scatton, Javoy-Agid, Rouquier, Dubois, & Agid, 1983). Hence the release of cortical dopamine following placebo manipulation has been investigated. For example de la Fuentes-Fernandes et al. (2001) found evidence of a placebo-induced release of dopamine in cortical pathways related to parkinsons’s disease equivalent to levels found in healthy volunteers after administration of amphetamine.

The evidence for the neurochemical mimicry theory of placebo effects is very persuasive and the studies that support the theory are well-replicated and well-designed. However there are several flaws with the approach and the evidence for it that warrant mention.

The first flaw is in the logic of the evidence for placebo analgesia being mediated by endogenous opioids. It is assumed that because naloxone is an opiate antagonist and because naloxone abolishes placebo analgesia that therefore placebo analgesia must be caused by an expectancy-induced release of endogenous opioids that dull the pain in a way that mimics the analgesic effect of administration of exogenous opiates. However since no studies have yet measured the release of endogenous opioids inside participants’ central nervous systems *directly* following their being given a placebo painkiller, it is impossible to be certain that naloxone does not have effects on some other non-nociceptive system that mediates the effect of expectancy on pain perception. Another way of putting this is that according to Benedetti and colleagues’ theory placebo analgesia works by releasing endogenous opiates which then act as a natural analgesic in much the same way as exogenous opiates, thus reducing the impact of the US by making it feel less painful. Endogenous opioids have multiple functions within the brain and central-nervous system beyond analgesia, such as regulation of mood, and, importantly for the current discussion, learning. For example it has been shown that naloxone enhances learning of second-order fear conditioning in rodents. When testing the effect of a drug such as morphine on fear conditioning, a stimulus such as a tone (CS­­1) is paired with a shock so that the shock comes to elicit a fear response. If rats given morphine during this procedure show an attenuated conditioned fear response compared to controls when presented with the CS1, it is difficult to know whether the effect is due to analgesia or to a failure to learn the CS1–shock contingency. In second-order fear conditioning once the conditioned fear response has been established a second stimulus such as a light (CS2) is paired to CS1 until a conditioned fear response is elicited by CS2 in the same way as it was to CS1. If morphine is administered to half the subjects after the CS1–shock pairing but *before* the CS1–CS2 pairing and the morphine group show attenuated fear response then there can be some certainty that morphine affected the *learning* of the association between the stimulus and the shock rather than the perception of pain from the shock itself. Cicala, Azorlosa, Estall, and Grant (1990) found that naloxone administered after CS1 –shock pairing but before the CS1–CS2 pairing enhanced learning of the second-order association, as measured by suppression of licking. It has also been shown that naloxone affects extinction learning. McNally, Pigg, and Wiedemann (2004) and McNally and Westbrook (2003) found that injections of naloxone into the periacqueductal grey of rats resulted in slower abolition of the conditioned fear response during extinction than saline-injected controls. A failure to learn a new relationship between the CS and US—that the CS no longer predicts the US—is analogous to a placebo effect which could be framed as a failure to learn that the drug vehicle no longer contains any active ingredients. That naloxone would impair the ability of rats to learn a new non-association between a CS and a US seems to contradict the fact that in humans naloxone seems to enhance extinction learning in that it blocks the placebo effect. There are also problems with the fact that naloxone enhances one type of learning in rodents, second-order fear conditioning, but impairs another, extinction learning. Irrespective of these inconsistencies, it appears as if there are grounds for thinking that naloxone affects learning itself in some way. Since the placebo effect is thought to be learning phenomenon, even by neurobiological theorists, it might be that naloxone’s ability to attenuate placebo effects might be due to its influence on learning rather than its blocking of the expectancy-induced release of analgesic endogenous opioids. Another similar but alternative explanation for the effects of opiate antagonists on placebo effects, proposed by Buchel, Geuter, Spranger, & Eiipert (2014), is that levels of endogenous opiates may act as a neuromodulatory ‘gating’ mechanism by increasing the certainty—or precision—of expectancies, i.e. acting on the CS rather than the US to increase certainty and thereby size of the placebo effects. Thus naloxone would inhibit the certainty with which the CS is seen as a predictor of the US. The naloxone studies mentioned above are the foundation upon which neurobiological theories of placebo effects are based. If the logic of the evidence for these assumptions is questionable then so must be the theories that are based on them.

The second problem is that global mechanisms such as release of endogenous opioids cannot explain the localised analgesia found in Montgomery and Kirsch (1996).

The third problem pertains to studies of placebo induced changes in Parkinsonian symptoms. Similarly to endogenous opioids, dopamine is a ubiquitous neurotransmitter in the brain, the scope of whose functions is still poorly understood. Its role in reward is well-founded. It may be that the improvements in motor function observed following sham deep brain stimulation and placebo injections were caused by an increase in dopamine in anticipation of receiving clinical treatment, i.e. of *general reward*, rather than any specific mimicry of the deep-brain stimulation device. Furthermore all studies mentioned were conducted on samples of ten patients or less, making the generalisability of these studies questionable. Goetz, Leurgans, Raman, and Stebbins (2000) found that in a sample of 105 Parkinsonian patients receiving placebo in a clinical trial for the drug ropinirole, only 16 percent showed a significant reduction in symptoms, and of that 16 percent none showed an improvement on all three visits. Lastly in Parkinson’s disease the *complete* absence of wilfull control over motor symptoms is rare. Thus the small improvements in motor function observed in patients led to expect an improvement over and above controls could be just as easily explained by an increase in self-belief or determination as by a conditioned mimicry of endogenous opioid release.

The fourth problem with neurobiological theories of placebo effects is that even if one accepts the assumptions made about the neurochemical mechanisms by which naloxone or rimonabant abolish placebo analgesia or by which expectancy improves motor performance in Parkinsonian patients, placebo effects can be observed across a wide range of sensory modalities. It is unlikely that placebo effects across all these modalities will have a readily identifiable neurochemical mechanism to mimic the effects of the active treatment in the same way as with placebo analgesia and placebo motor control changes in Parkinson’s disease.

*Perceptual Shift*: Though the neurochemical mimicry theory discussed above concerns itself principally with the physiological and neurochemical mechanisms of placebo analgesia, implicit within it is the assumption that beliefs about having consumed an active drug produce responses that mimic the effects of the active drug by activating the same neurochemical systems utilised by the drug itself. This can be contrasted with information processing theories that suggest that placebo effects are caused by attention-mediated perceptual shift and that the brain mechanisms responsible for attention and perception of interoceptive signals are also responsible for placebo effects (Büchel et al., 2014; Melzack & Wall, 1967; Wall, 1993). These theories will be discussed in more depth in the section titled ‘Perceptual Shift’ below, however, briefly, they suggest that higher brain areas responsible for prior beliefs and lower brain areas transmitting signals from the peripheral nervous system meet and interact at the dorsal horn of the spinal column. Projections from cortical areas responsible for prior beliefs are able to inhibit or facilitate signals travelling from the peripheral nervous system to the higher perceptual processing areas, thus prior beliefs can override or attenuate pain signals. However the relationship between bottom-up peripheral signals and top-down cortical signals is not one-way. If the signals from the sensory organs are strong enough it and persistent enough they can override the influence of prior beliefs so that the beliefs are changed. The chief advantage of this theory is that this single mechanism could easily be applied to all placebo effects across all sensory modalities, not just pain.

## Other explanations of placebo effects

The theories discussed above concerning the source of placebo effects all carry assumptions, either implicit or explicit, that a mistaken impression about the likely effect of a treatment can cause some *real* change in the relevant system within the individual. For example pain can be caused by tissue damage or inflammation or, in the case of headache, dilation of blood vessels. Pain signals travelling from the site of the tissue damage or inflammation travel via the peripheral nervous system to the central nervous system where they are detected by the brain and registered as the subjective experience of pain. The conditioned response of the brain upon registering this pain is to produce endogenous opioids, which then attenuate the strength of the pain signals. However these endogenous opiates only attenuate the sensation of pain so far. A *voluntary* response to pain is to take an analgesic. Analgesic medicines contain chemical agents that work by suppressing either the chemicals that produce the inflammation themselves, in the case of prostaglandin suppression by non-steroidal anti-inflammatories, or the pain *signal*, by binding to relevant receptors in the central nervous system in the case of opioid-based drugs. Theories of placebo effects must be able to explain the fact that individuals in placebo groups reliably report different levels of the target variable than controls despite receiving the same painful stimuli. The assumption in the neurobiological theories discussed above is that the mistaken belief that one has ingested a painkiller causes an additional release of the chemical agents that ameliorate pain, *over and above* the endogenous opioids already released by the central nervous system as a compensatory response to the sensation of pain. That is, the belief that one will be receiving pain relief causes a *direct* change in the systems responsible for pain relief. This direct change is then perceived by the individual and reported back to the researcher.

There are other theories about how changes in observed symptoms following an inert treatment occur. All of them fall into the category of what has traditionally been termed ‘response bias’. It is here that it becomes important to distinguish between placebo effects and placebo responses. Up until this point I have been using the term ‘placebo effects’ as an umbrella term for any observed change caused by something other than the inherent properties of that treatment. However observed change could be caused by factors other than a real change in the variable of interest. A placebo response is defined by Stewart-Williams (2004) as “any change that occurs after the administration of the placebo” (p. 199). A placebo effect on the other hand is “that proportion of the placebo response that is attributable to the placebo; that is, it would not have occurred if the placebo had not been administered.” (p. 199). The reason it is important to distinguish placebo responses from placebo effects is that, in clinical trials that have a placebo control group but have no no-treatment control group, often any improvement or change following the administration of the placebo it attributed to placebo, whereas it could simply be the natural effects of healing over time or spontaneous remission. Determining what portion of observed placebo responses are due to genuine placebo effects and what portion are due to response bias can be extremely difficult, especially in research into subjective variables such as pain which often *only* be measured by self-report. Research into variables that cannot be measured objectively must assume: (1) that participants are able to access and accurately report their attitudes and perceptions; (2) that if they are able to appraise these variables accurately, that they will then decide to truthfully report this to a third party. Whether these assumptions are justified is a matter of considerable debate in the life and health sciences. Because of these measurement difficulties it is hard to accurately estimate the extent to which response bias affects behaviour and reports of subjective phenomena. In fact there some researchers have offered evidence that placebo effects may be mostly response bias (Hróbjartsson & Gøtzsche, 2001). Furthermore in some cases the *conceptual* division between real effects and bias is not clear. Therefore a discussion of these sources of bias is warranted. There are many models of response bias (e.g. Colagiuri and Lovibond, 2013) , however I have classed response bias into four categories: intentional deception, conscious response shift, self-deception, and mediation.

### Intentional Deception

Colagiuri and Lovibond (2013) define demand characteristics as changes in responding brought about via a belief held by participants about the aims of the study or treatment. Implicit in this definition is that the participant changes their response because they wish to please the experimenter rather than because the variable of interest has actually changed[[1]](#footnote-1). Also implicit in the definition is that the participant is *aware* that the level of the variable that they report to experimenters is different to or unrelated to the true level they actually experience. Thus I have termed this source of placebo responding intentional deception. The existence of intentional deception, however well-meaning, is a problem because instead of measuring change in a variable of interest what is being measured is participants’ guesses about what they think the experimenters want them to do or to report, which compromises the validity of any findings, both in experimental or clinical research. Knight, Barbaree, and Boland (1986) attempted to estimate the extent of intentional deception in psychological experiments via the use of a sham computer-malfunction at the end of an experiment whose ostensible purpose was to measure the relationship between alcohol and sexual arousal. In a balanced-placebo design participants were given either alcohol or placebo as a beverage. The flavour of the alcohol was masked so that participants could not determine, based on its taste, whether the beverage contained alcohol or not. Within the alcohol and placebo groups participants were then either told that they had received alcohol or placebo. Thus two groups of participants received information about the alcohol content of their beverage that was congruent with actual alcohol content and two groups received incongruent information. Participants were then given pornographic material and asked to rate their arousal. After the study participants were given a computer-based manipulation check where they were asked to rate whether or not they had been given alcohol. At the conclusion of the final question a sham computer error message appeared on the screen. The researcher then told the participant the true design of the study and that the participant could have been given placebo or alcohol but that the computer error had caused the information about which they had actually received to be lost. Participants were then asked a similar set of questions to the first manipulation check by the experimenter. Estimates of alcohol content in the incongruent groups changed dramatically from the pre- to the post-computer-malfunction manipulation checks in the incongruent groups but changed very little in the instruction-congruent groups. Furthermore the variance in alcohol estimates explained by instruction and actual alcohol content in the pre-computer-failure manipulation check was .52 and .08 respectively; however in the second manipulation check the variance explained essentially switched to .05 and .53 respectively. Even if the change from the first to the second manipulation check was *also* caused by demand characteristics this is a dramatic example of the bias of self-reports and behavioural measures that can be caused by conscious deception on the part of participants.

A technique for reducing intentional deception is to conceal the true purpose of the study so that participants do not know what precisely is being demanded of them. For example several studies into the effects of caffeine and caffeine withdrawal conducted at John Hopkins University instructed participants to abstain from multiple types of food and beverages, even those not containing caffeine, so that participants would not exaggerate or downplay their symptoms (Garrett & Griffiths, 1998; Jones, Herning, Cadet, & Griffiths, 2000; Schuh & Griffiths, 1997; Silverman, Evans, Strain, & Griffiths, 1992). However even if the true variable of interest is concealed participants may still make guesses about the purpose of the study and amend their responses accordingly and that this may indirectly affect the way they respond to the variable of interest. Thus this technique does not completely eliminate response bias brought about by intentional deception. Another technique is to thoroughly question participants, both in person and via questionnaire, what they believed the true purpose of the study was and/or what their beliefs were concerning the experimental manipulation (e.g. whether they believed that they received an active drug or a placebo). However even in these debriefs participants may choose to deceive experimenters as to what they believed and how they felt.

Intentional deception is a clear example of a bias that may obscure a true effect. Even with the measures described to reduce its influence it remains a confound whose true contribution to observed placebo responses remains very difficult to estimate.

### Conscious Response Shift

Wilson (1999) defines response shift as a change in the meaning of one’s self evaluation of a target construct. There are two types of change that would result in response shift: beta change, which refers to scale recalibration, and gamma change, which refers to concept redefinition (Norman & Parker, 1996). An example of recalibration supplied by Wilson (1999) is of a woman who reports relatively low stress before an intervention, but who, as a result of the intervention, considers her stress levels and comes to the conclusion that she was under more stress than she had previously thought and so reports more stress after the intervention than before. The woman’s actual stress levels have not changed due to the intervention but the intervention has caused her to reappraise her stress levels and adjust her reports upward. An example of concept redefinition is a man who reports low levels of stress prior to an intervention at his workplace. During the intervention he is made aware that there are several types of stress—work stress, marital stress, positive stress, acute stress, chronic stress. He realises that he was only considering work stress when he answered on the pre-intervention questionnaire and because his conception of ‘stress’ has changed he reports higher stress post-intervention, even thought he is not any more stressed than he was before the intervention. Both examples will result in an observable change due to an intervention, but neither change is due to the effects of the intervention on the true level of the target construct itself. This will violate the assumption of psychometric testing, that a common metric exists across time on the same test taken by the same person, and thus if there is a change between tests it represents a true change on the variable of interest. If the metric changes due to response shift then this constitutes bias that will distort the observation of the change in the true score and affect the reliability of inferences about causes of change in that variable.

The chief method of assessing response shift is the Then/Post test, developed by Howard et al. (1979) after they observed a clear increase in dogmatism following an intervention designed to reduce dogmatism. The instructors involved in the intervention were skeptical of this result, having witnessed the behavior of the participants during the intervention workshops. The change results were not inconclusive, which would usually occur if the measurement instrument were at fault. Thus it was theorised that the change came from another source. When questioned in post-test interviews participants indicated that the intervention changed their *perception* of their *pre-test* dogmatism, which meant that between the first and second they had recalibrated the scale by which they judged their own dogmatism, so that even thought the intervention reduced their dogmatism, their post-test score revealed a higher level of dogmatism. In a second study, to counteract this response shift, only one questionnaire test was given to half of participants at the conclusion of the study. This test asked them to rate their current (i.e. post-intervention) level of dogmatism, and also to retrospectively rate their pre-test levels of dogmatism. The other half of participants were given the same dogmatism test pre- and post-intervention. Significantly more individuals in the group who received the Then/Post test reported an improvement in dogmatism than in the Pre/Post test. This result indicated that the counterintuitive increase in dogmatism in the first study was due to a scale recalibration rather than an actual increase in dogmatism. Then/Post designs have also been used to measure response shift in quality of life (Ahmed, Mayo, Wood-Dauphinee, Hanley, & Cohen, 2004; Ring, Höfer, Heuston, Harris, & O'Boyle, 2005) and self-reported pain (Razmjou, Yee, Ford, & Finkelstein, 2006) with similar results.

The concern in studies of the placebo effect is that any change following a placebo treatment is due to a scale recalibration or reconceptualisation rather than an actual change. For example if, in an experiment investigating the role of expectancies in pain, there is a decrease in pain ratings from pre- to post-test in subjects given placebo, it may be that this decrease is due to their using a higher criteria for rating pain. This change in their benchmark for assessing pain levels might be caused by their thinking about the questions they were asked in the first questionnaire and, in the interim between this and the second questionnaire, deciding that their first rating was too high. Thus even though their level of pain has not changed following the placebo, they rate their pain level as less.

The fact that individuals in the Howard et al. study were able to explain their recalibration in terms of a re-appraisal of their prior attitudes implies that to some extent at least the scale recalibration was a conscious one. There are forms of response shift that are not mediated consciously at all. I have grouped these forms of response shift under the umbrella term self-deception.

### Perceptual Shift

In contrast to intentional deception, perceptual shift is a form of self-deception (Kirsch, 1999). In this context self-deception refers to the individual being unaware of the true motives or causes for the way they behave or feel. The important difference, for the purposes of this discussion, between intentional deception and conscious response shift on one hand and perceptual shift on the other, is that intentional deception and response shift take place independently of belief, and thus may obscure expectancy effects, whereas perceptual shift can either be caused by expectancy or give rise to it. In this sense it is difficult to truly class self-deception as a source of bias—i.e. as a variable that obscures the true expectancy effect—since it may be in fact be synonymous with the expectancy effect itself.

Perceptual shift is a form of response shift in the sense that it is a change in responding brought about by something other than an actual change in the system in question. The difference between perceptual shift and conscious response shift is that perceptual shift occurs without any conscious appraisal, whereas conscious response shift usually takes place with variables that involve awareness and which are more cognitively mediated (e.g. dogmatism, quality of life).

In direct contrast to the idea that placebo effects are caused by a direct change in the system responsible for the action of the active treatment, is the idea that subjective placebo effects come about by a change or recalibration of the individual’s attitude towards a sensation. This may cause the perception of the sensation to change even thought the actual stimuli (e.g. tissue damage or inflammation in the case of pain, or build up of histamines in the case of alertness) that caused the original sensation has not changed. As mentioned some, like Kirsch (1999), call this form of placebo response ‘self-deception’, others call it response shift, but this misrepresents the phenomena. There is growing evidence from research using Bayesian information processing models that perception, across multiple sensory modalities—visual, auditory, haptic, olfactory, interoceptive, nociceptive, and even affective—is an inferential process, where the data that comes from our senses is integrated with our prior beliefs, each being weighted by their relative certainties, resulting in a final perception that informs our actions. Bayesian models of perception are based on Bayesian statistical analysis. Bayesian statistics represent a way of mathematically expressing the likelihood of some underlying state of the world (i.e. some fixed parameter value on a given outcome variable) given an observed set of data and our prior beliefs. The implications of Bayesian data analysis and Bayes’ rule is that our appraisal of the underlying patterns in the world is a function of: (1) what we believe before we receive information, (2) the information itself. What determines the relative contribution to each of these factors to our final appraisal or perception is the relative certainty we have about each.

The idea that our expectancies influence the way we perceive the world has been studied for many years across many different disciplines and under many different names. The Gestalt Psychologist Solomon Asch conducted research into the effect positively- or negatively-valenced trait descriptors can have on the perception of subsequent behaviour (Asch, 1946). He found that certain descriptors were more central than others and that the valency of these central trait descriptors change the way that other more ‘peripheral’ traits were perceived by the observer. Participants were given vignettes to read which described a hypothetical person. Prior to reading the vignettes the hypothetical person was labeled with a trait descriptor. Asch found that labeling this person with the words ‘warm’ or ‘cold’ prior to participants reading the vignette could have fundamental and predictable effects on the overall impression people formed of the hypothetical individual’s character. Importantly, identical peripheral traits could be perceived vastly differently depending both on the valency of the central trait descriptor and the order in which the subsequent trait descriptors were presented.

Social information processing theory states that ambiguous social cues can be encoded in a way that is consistent with the pre-existing schemas held by the observer of those cues. The nature of these schema influence the way the observer perceives the valency, intensity, and meaning of the cue. For example the cognitive model of social phobia (Clark & Wells, 1995) proposes that sufferers of social anxiety tend to interpret ambiguous social cues negatively, in line with the way they feel about themselves. The focus on negative interoceptive information concerning the way they feel then shifts attentional focus away from the true features of the external situation and makes the sufferer feel like they are the centre of attention, which exacerbates their anxiety. This theory has been confirmed by findings from clinical studies where participants with social anxiety were more likely to interpret ambiguous descriptions of social events (e.g., “someone you are dating says ‘hello’ to you”) as being negative than either nonpatient controls or controls with other anxiety disorders (Amin, Foa, & Coles, 1998; Stopa & Clark, 2000). Furthermore participants with social anxiety were more likely to interpret mildly negative social events as being catastrophic than either of the two control groups (Stopa & Clark, 2000). These findings support the theory that individuals with social phobia have a cognitive schema that biases them to interpret otherwise ambiguous social cues as reflecting others’ disapproval and dislike. The second part of the theory follows from the first. The shift of attention moves away from the objective features of the situation inward, towards interoceptive stimuli (see Clark & McManus for a review). This has also been backed up by experimental findings that show that individuals with social anxiety exhibit an attentional bias away from faces when under conditions of social threat (Mansell, Clark, Ehlers, & Chen, 1999) and poorer recall of details of recent social interactions (Daly, Vangelisti, & Lawrence, 1989; Hope & Heimberg, 1988; Kimble & Zehr, 1982; Mellings & Alden, 2000).

There is evidence that information processing biases may be involved in the maintenance and aetiology of other disorders. Analogous to individuals with social anxiety disorder, individuals with conduct disorder (Dodge & Crick, 1990) and eating disorders (McFillin et al., 2012) have been shown to be more likely to interpret ambiguous social cues as signaling hostile intent. In the different disorders studied the stimuli are the same; ambiguous social cues.

What differs between the disorders mentioned is a) the pre-existing schema held by the individual concerning the meaning and intentions of the other people in the social situation from whom these cues originate and b) the concomitant response that is elicited by the resulting misinterpretation. However what is *common* in all these disorders is that individuals with the disorder interprets the ambiguous information in line with their own pre-existing schema.

So in the case of both the effects of labeling on perception of personality traits and in the way individuals with various mental disorders perceive threat in social situations we can extract commonalities in the underlying processes of each:

1. the existence of a schema or belief
2. which elicits an attentional bias ,
3. which, when a certain class of stimuli is presented, results in a misinterpretation of the objective features of the situation
4. which in turn elicits an emotional, cognitive, behavioural, or somatic response.

The previous examples pertain to perceptions of unobservable phenomena (i.e. personality and intent of others in social situations), both of which would appear to be a more indirect, subjective, and hermeneutic exercise than perception of the senses, since it involves inferring unobservable constructs (the ‘traits’) from direct or third-party observations of behaviour. However even more ‘direct’ perceptions can be biased by contextual information. For example when white wine is coloured red with food dye it is perceived as having the odour of red wine (Morrot, Brochet, & Dubourdieu, 2001). Also experienced wine tasters rated white wine coloured the same colour as Rosé as being sweeter than uncoloured white wine (Pangborn, Berg, & Hansen, 1963) Furthermore accuracy in judging the taste of nectars was found to be reduced when the nectar was coloured than when it was uncoloured (Pangborn & Hansen, 1963). These are examples of one perception, taste, being moderated by the information from another, vision. Another study found a relationship between temperature and perceived taste. Zellner, Stewart, Rozin, and Brown (1988) allocated participants to two groups, Expectation and No Expectation and gave each participant the same juice twice, once warm and once cold. The Expectation group were told that the juice was consumed warm in the tropics. The No Expectation group were told nothing. Participants in each group were asked to rate which juice they thought tasted better. Participants in the Expectation group rated the warm juice as tasting better than the cold whereas the No Expectation group rated the cold juice as tasting better. There are also examples of non-perceptual, cognitive information affecting perception of taste. One study, for example, found that consumers could not distinguish their favourite brand of cola or beer above chance from other brands when blindfolded (Sheen & Drayton, 1988), and that consumers rated the same beer as tasting better when it displayed a label than when it did not (Allison & Uhl, 1964). Attempts to explain these findings led to the development of assimilation/contrast theories (Anderson, 1973), which explain taste perception in terms of an integration of expectation and sensory information. Despite originating in market research and consumer science the framework and language used share many similarities to both expectancy theory and cue integration theories of sensory visual and auditory perception. Assimilation/contrast theory is based on theories of cognitive dissonance (Festinger, 1962), which state that when an individual is confronted with ideas or perceptions that are psychologically dissonant, they will experience discomfort. In order to minimize this discomfort they will distort their evaluation of one or more of these ideas or perceptions in order to make them more compatible with one another. In assimilation/contrast theory any discrepancy between expected taste and actual taste will be minimised or ‘assimilated’ by the consumer in order to bring the perception more in line with the expectation. The opposite of assimilation theory is contrast theory, which states that some consumers, when confronted with the disparity between expectation and sensation, will magnifythis disparity between the two rather than minimising it. For example Carlsmith and Aronson (1963) found that participants led to expect sweet juice but actually given bitter juice or led to expect bitter juice but actually given sweet, rated their juice as being more bitter or more sweet respectively than participants who were given no prior instruction as to the juice’s taste. This was taken as an indication that participants whose expectations were incongruent with their eventual perception favoured the perception and upregulated the difference between it and the expectation. Assimilation/contrast theory integrates the two theories, proposing that each individual has a threshold for the degree of dissonance they will tolerate. Beneath this threshold level of dissonance they will assimilate their perception in the direction of expectation. Above this threshold they will magnify the difference. This theory is appealing in that it can explain why some consumers are highly influenced by suggestion and expectation whereas other are not; however without awareness of each individual’s threshold the theory becomes unfalsifiable. Despite this, the similarities between assimilation/contrast theory and expectancy theories of placebo effects are obvious.

The findings discussed above led Morrot et al. (2001) to state: “Our results tend to confirm that sense of smell is, by itself, unlikely to provide sufficient information to allow for a consciously reasoned decision, as it is for other sensory modalities.” Taste it seems is an unreliable sense, one that is prone to alteration by other sources of information. However it is not the only unreliable sense.

Even auditory and visual perception are susceptible to corruption by information. Körding and colleagues (2007) found that estimates of the location of the source of a sound could be biased by presenting visual stimuli to one side of it. In perception research this phenomena is called cue integration. The ability of the visual stimuli to bias the subsequent estimates of the auditory stimuli depended on the distance of the light from the auditory stimuli. If the visual stimulus was very close to the auditory stimuli it had very little effect. If the visual stimulus was too far away it also had little effect. However if the visual stimulus was a moderate distance away it was able to significantly bias estimates of the location of the auditory stimuli. Importantly when the situation was reversed and auditory cues preceded the visual stimuli, the auditory cues had less of a biasing effect on estimates of the location of the visual cue than visual cues did on the location of auditory cues. This asymmetry in the ability of one sensory modality to bias perception of the other supports the conclusion that different sensory modalities have different degrees of sensory precision and that the degree to which sensory information is able to be biased by prior information is contingent not only on degree of certainty of the prior information, but also the degree of certainty or precision of the sensory domain. Wall (1993) has advocated a similar position in his Response Appropriate Sensation theory, stating that certain perceptual domains, such as sound and vision, are more ‘stimulus invariant’ than other, more interoceptive domains, such as pain, hunger, thirst, vertigo, fatigue, and feeling too hot or cold. In less precise perceptual domains current perception will be more easily influenced by prior information and beliefs than will more precise domains such as sound and vision.

The findings of Körding et al., and those of other studies (Weisswange, Rothkopf, Rodemann, & Triesch, 2009; Yu & Dayan, 2005) indicate that, even in ‘hard’ perceptual domains such as sound and vision, *perception is an inferential process* (Shams & Beierholm, 2010), one where prior and current information are integrated together to arrive at an estimate, with the relative weighting assigned to each in deciding this estimate determined by their relative uncertainty. The similarities of these findings to the evidence previously cited from abnormal psychology and from taste perception are clear and lead to the conclusion that, across many sensory domains, perception of sensation is dependent on the integration of prior beliefs with current information.

Bayesian statistical modeling involves the integration of prior beliefs with current data to derive probabilistic estimates of the underlying processes within a given system. In Bayesian models prior belief about the probability of given parameter value is expressed via a probability density function (probability of an outcome given a fixed parameter value) whereas current data is expressed via a likelihood function (probability of an underlying parameter value given a fixed outcome). These two distributions are integrated via Bayes’ Theorem to form a final estimate of the underlying parameter value. This estimate is expressed via the posterior probability distribution, which is proportional to the product of the prior and the likelihood distibutions (Kruschke, 2014). The influence that the prior and the likelihood function have on the posterior is weighted by the relative level of uncertainty of each. Uncertainty in Bayesian modeling is expressed via the precision of the distribution of a function. In simple terms the precision of a distribution is expressed by its width and its height: The narrower and taller the distribution the greater its precision and the greater its influence on the posterior.

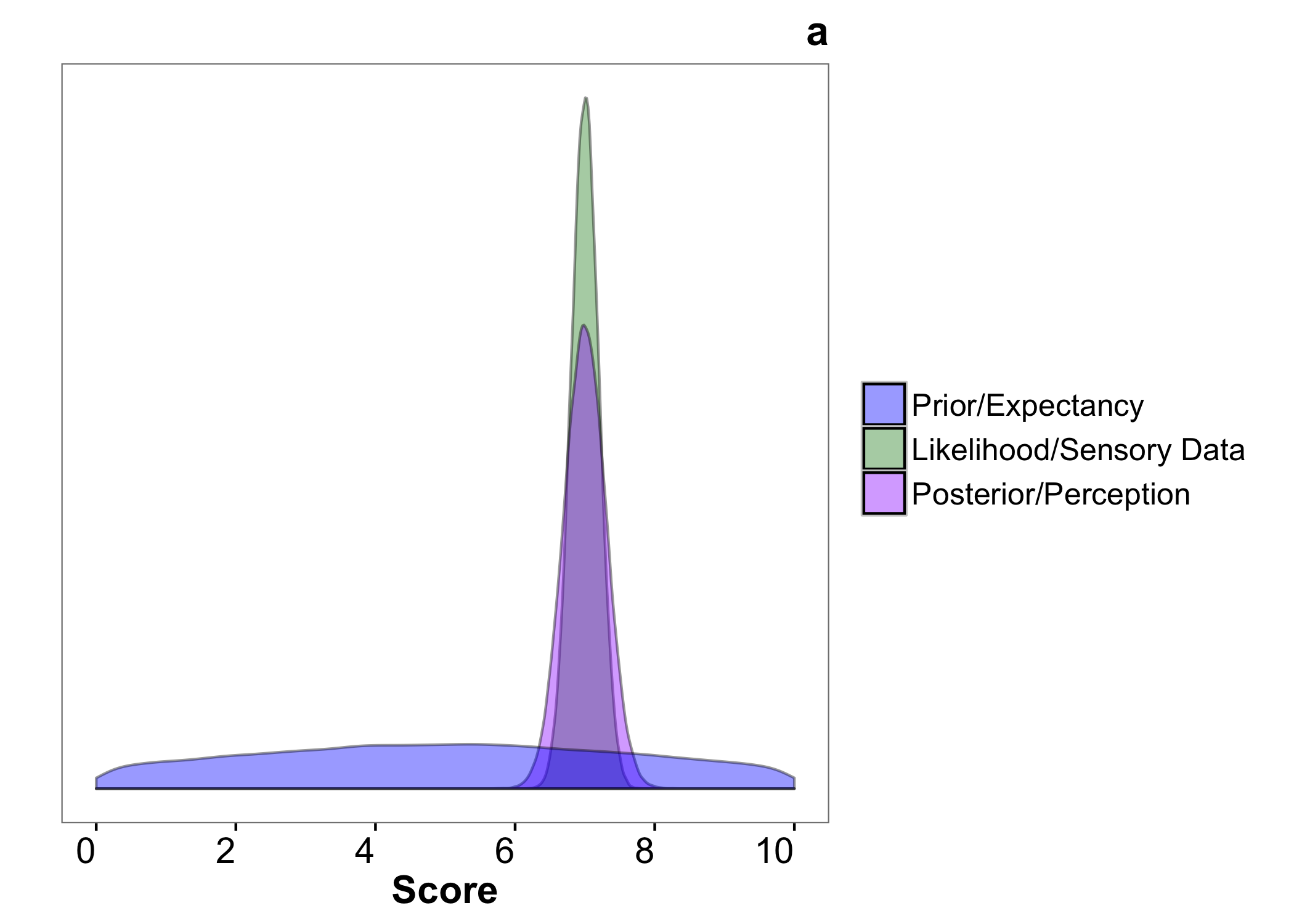
Like conditioning and expectancy models of classical conditioning, Bayesian models of perceptual information processing are easily translatable to models of placebo effects. Arising out of contemporary theories applying Bayesian ideas to brain function, Büchel, Geuter, Sprenger, & Eippert (2014) have developed a Bayesian model of placebo effects that integrates contemporary neuroscience with findings from placebo research. The authors of this model suggest that it can explain many facets of placebo analgesia and other placebo effects. They propose that placebo effects take place via a process of reciprocal neural communication, between ascending signals projecting from lower-order sensory neurons in the peripheral nervous system (i.e. sensory data) and descending projections from cortical areas such as the rostral anterior cingulate cortex, anterior insula, amygdala, hypothalamus, and periacqueductal grey (prior beliefs). These ascending and descending signals intersect at the rostral ventromedial medulla which sits at the dorsal horn of the spinal column and exert reciprocal influence on one another in an iterative fashion. The interesting part of this reciprocal loop for the purposes of the present discussion is that the cortical signals can exert inhibitory or facilitatory control over the signals travelling up from the peripheral nervous system. Interestingly these findings from modern neuroscience confirmed a theory put forward as far back as 1965. Melzak and Wall’s ‘gate control theory’ postulated a mechanism somewhere in the spinal column whereby signals from the peripheral nervous system could be attenuated or ‘gated’ on their way to areas responsible for perception of pain, by projections from the higher brain areas responsible for “attention, emotion and memories of prior experience to exert control over the sensory input.” This theory was not confirmed until recently by studies showing spinal involvement in placebo hypoalgesia (Eippert, Finsterbusch, Bingel, & Büchel, 2009; Matre, Casey, & Knardahl, 2006). Büchel and colleagues’ (2014) model extends the gate control model, but suggests that, rather than separate top-down and bottom-up systems, a single reciprocal, iterative system whereby data from the senses and from prior beliefs are in constant communication with one another to inform sensation from one moment to the next such that if beliefs no longer match sensory data that data can cause those beliefs to change. This reciprocal interactive model may help explain why placebo effects extinguish over time—because the signal from sensory data becomes sufficiently certain (either from amplitude of signal or consistency over time) to override control by prior beliefs. Büchel and colleagues’ model is a neural model of placebo effects based on *control of perception by both attention, belief, and sensory data*, where prior beliefs inhibit or enhance signals coming from the peripheral nervous system to produce a resultant sensation and where signals from sensory data can modulate beliefs. That the size of the placebo effect is determined by the level of certainty was shown in a study by Brown and colleagues (2008), who examined the effect of different intensities of painful stimuli under both certain and uncertain expectation conditions. They found that under certain expectation conditions high intensity pain was perceived as more painful and low intensity as less painful, which would confirm that certain prior beliefs can modulate existing sensory signals. Other studies have found results that seem to contradict Brown et al. (2008), with uncertainty producing increased pain for the high intensity pain stimulus (Yoshida, Seymour, Koltzenburg, & Dolan, 2013). Pollo et al. (2001) discovered that telling participants they would receive a painkiller (exact instruction) produced more pronounced placebo analgesia than instructions that they could receive either a painkiller or a placebo (uncertain instruction), which supports finding from other studies that uncertain instruction can produce differing effects to deceptive instruction (Kirsch & Rosadino, 1993; Kirsch & Weixel, 1988).

In Bayesian statistical models the prior probability function is analogous to prior beliefs or expectancy in expectancy models of placebo effects, and the likelihood function is analogous to perceptual information from the senses (Büchel et al., 2014). In Bayesian placebo models the final perception is the result of the integration of these two sources of information. According to these Bayesian models the level of certainty with which the expectancies are held will determine the strength of their influence on the final perception. Thus the more certain the expectancy the greater the placebo effect. We will now offer some examples to illustrate how this model might work.

Let us imagine an experiment where participants rate pain levels around an electrical shock to the skin of the hand. The abscissa of the three distributions represent level of pain, where 10 is maximum pain and 0 no pain. The y-axis represents probability density, or level of certainty. Prior to each shock participants either have an inert cream applied or they are given no cream. The participants are told that the cream is a powerful analgesic that will reduce the painfulness of the shock. Prior to each shock they are asked to rate how painful they believe the upcoming shock will be. This is represented by the distribution labeled ‘Prior/Expectancy’. A rating of 8-10 would indicate a belief that there will be little to no analgesia, that is, a strong and painful shock. A pain rating of 0-3 would indicate strong analgesia/low pain. The second distribution ‘Likelihood/Sensory Data’ is how strong the shock delivered actually is. The third distribution ‘’Posterior/Perception’ represents a rating of how strong the final perception of pain is after the shock has been delivered. There are two things to consider for each scenario:

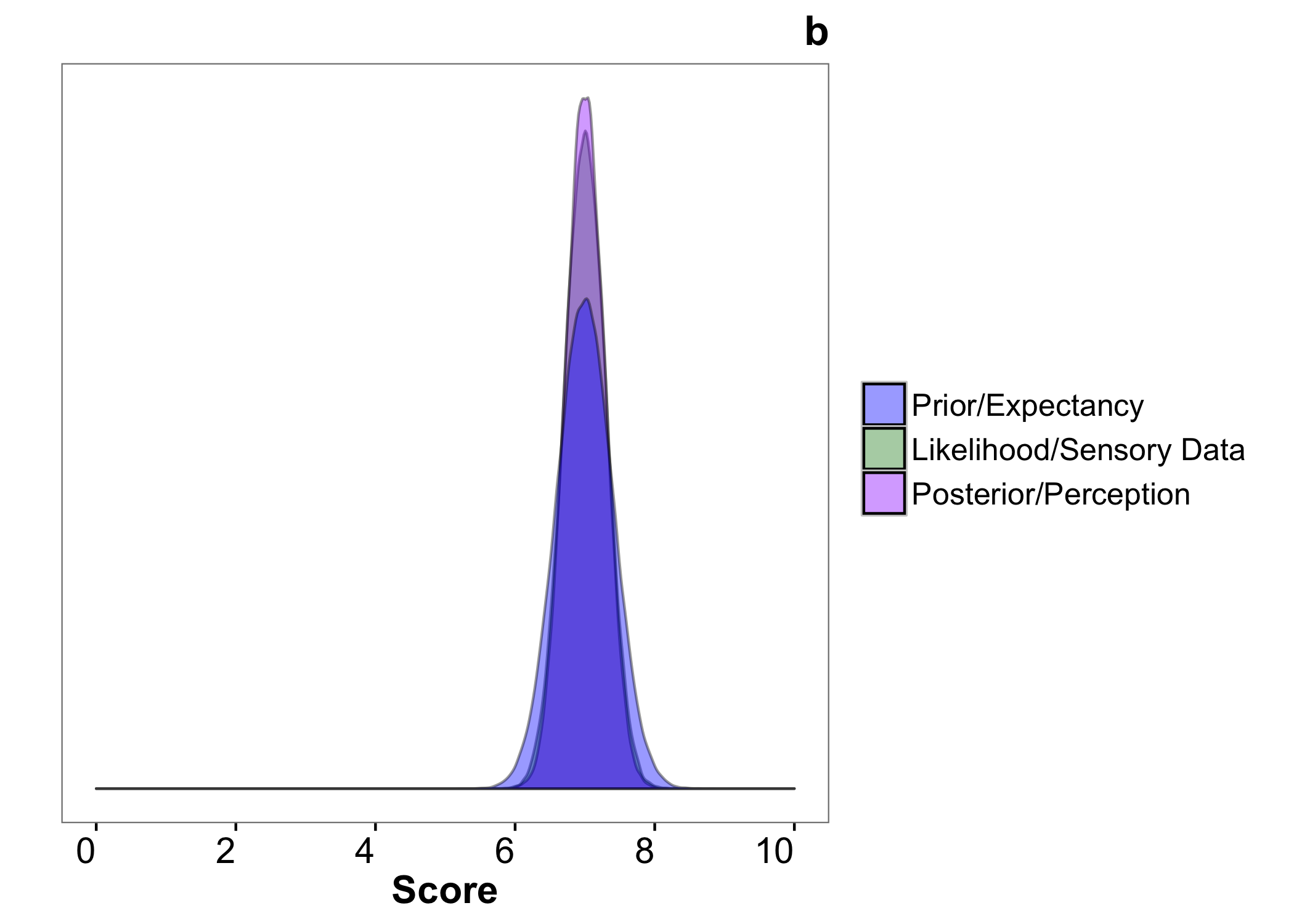
* *Congruence* of expected pain vs actual pain signal, expressed by relative positions on the x-axis of the mode of the prior and data distributions.
* *Level of certainty* of expected pain vs actual pain signal, expressed by the characteristics of each distribution (width of distribution and height of distribution)

For the first example, in figure (a) let us say that this is the first trial in the calibration phase of the experiment. Participants have not yet had the cream applied nor been told anything about it, and are merely asked to rate their pain before and after the shock.



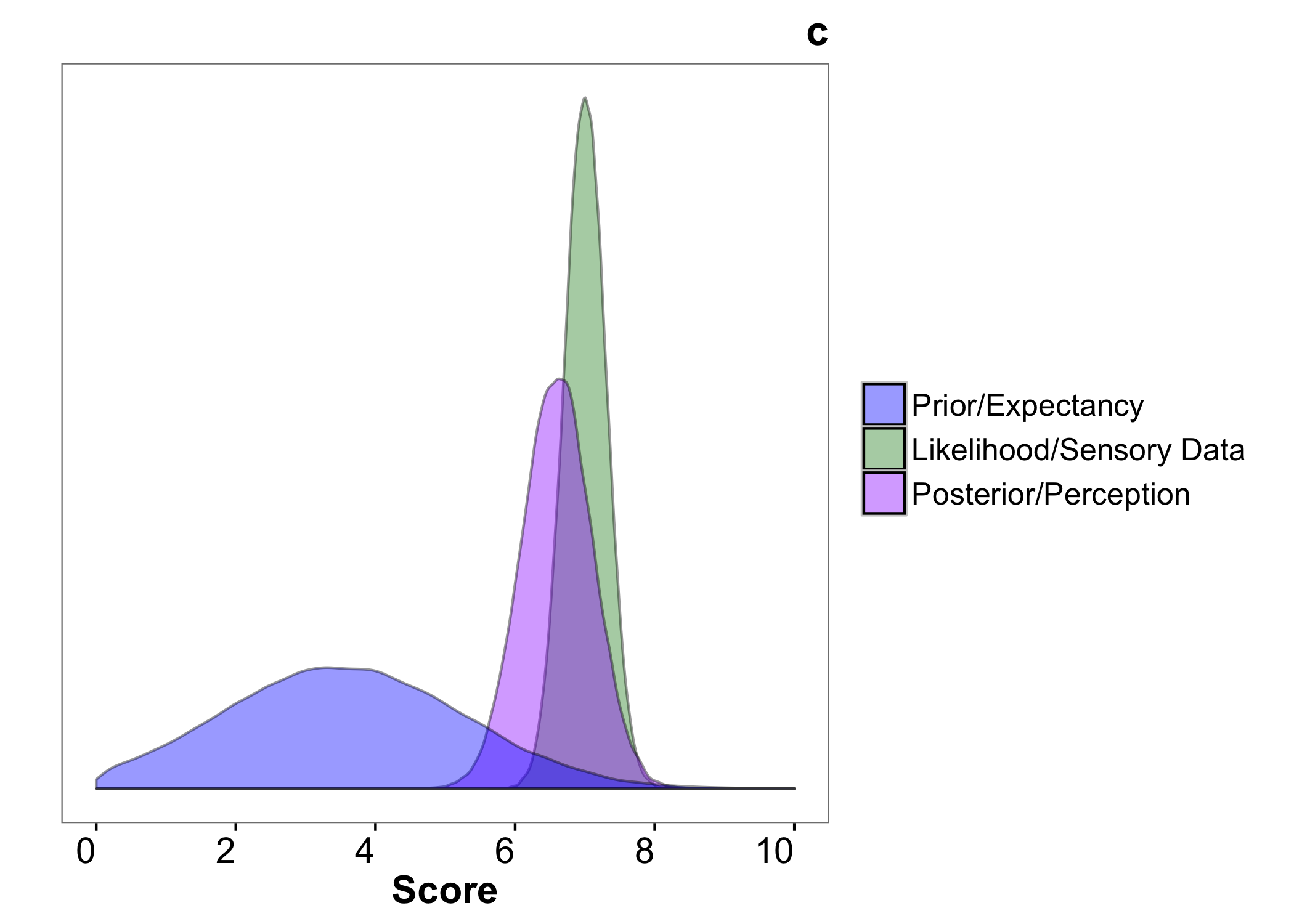
Because there is no expectation of what the upcoming pain will be—represented by the wide, diffuse prior with probability low and spread approximately evenly over the entire range of possible pain levels—the prior has no influence over the final perception. Thus the shock level and the final perception are almost identical.

The next example, in figure (b), is a representation of the model prediction for participants’ final pain ratings when the information they have been given is congruent with the final shock level. An example of this would be when participants have finished the training phase and have experienced the shocks, and have been given no cream. The following represents the first no-cream trial of the test phase.



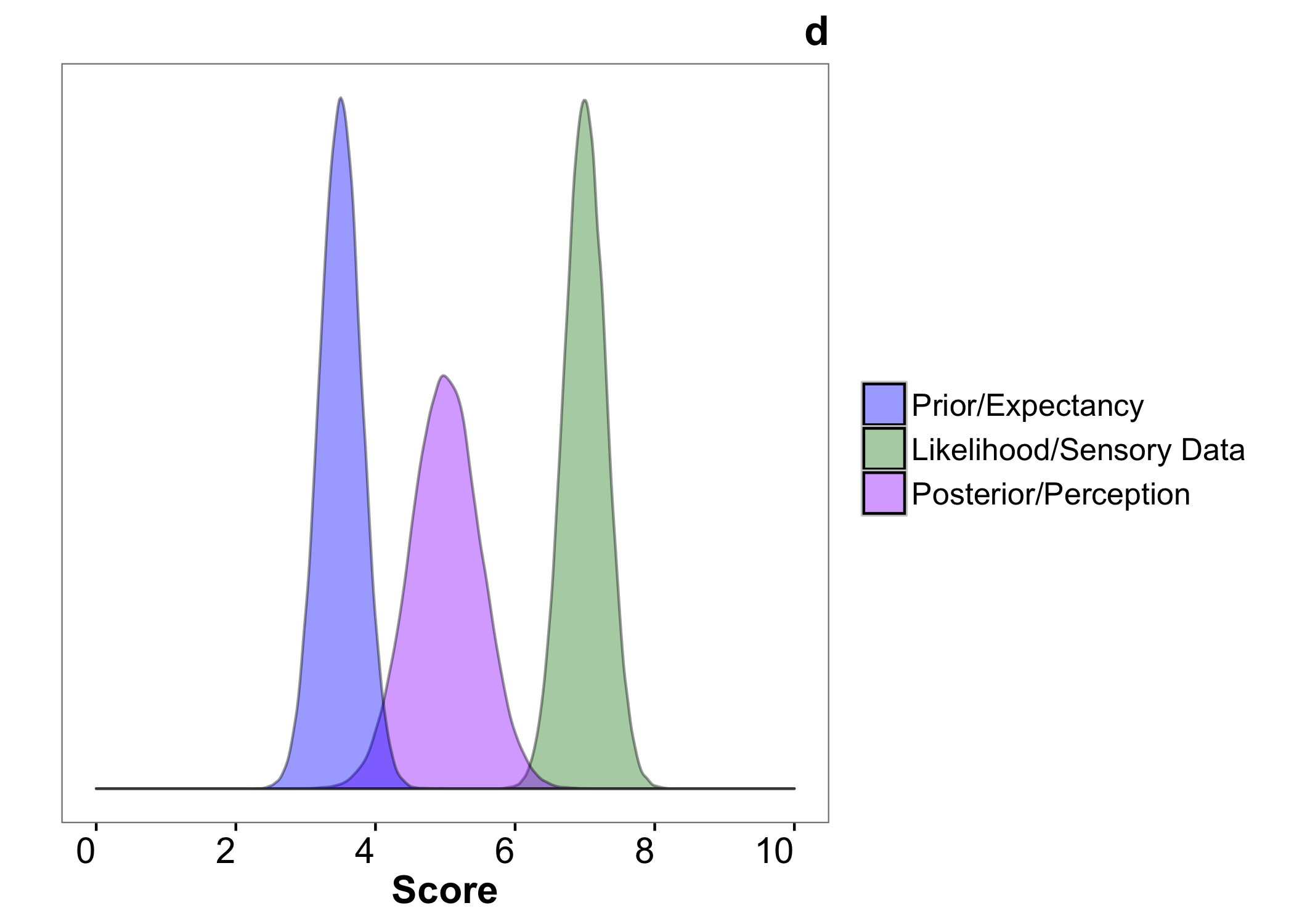
Here the final perceived pain, represented by the posterior distribution, is much the same as it was in example (a). The expectation of pain is congruent with the actual received pain, so the perceived pain is the same as both expected and actual pain delivered.

Now we will look at how placebo effects take place in a Bayesian model. Suppose that prior to the test and training sessions, during the consent process, participants are told that they have equal chance of receiving an active treatment, that is real analgesic cream, or an inert placebo cream. Now under these conditions let us imagine that the participant has the cream applied. Now consider figure (c). The shock level delivered is the same as in scenario (a) and (b) but now they have a belief that they may experience some analgesia (i.e. lower pain). However because of the instruction that they *could* receive a placebo, their belief is not very strong (represented by a widely-distributed prior centred around 3.5.



Now, because the expectation and the actual shock are no longer congruent there is a placebo effect, with the perceived pain lower than it was in (a) and (b) despite receiving the same shock level. This fact is reflected in the graph by the fact that the posterior distribution is centred on a lower pain rating than the sensory data distribution. However the placebo effect is not very large on this occasion, due to the fact that the belief in the analgesia was not very certain.

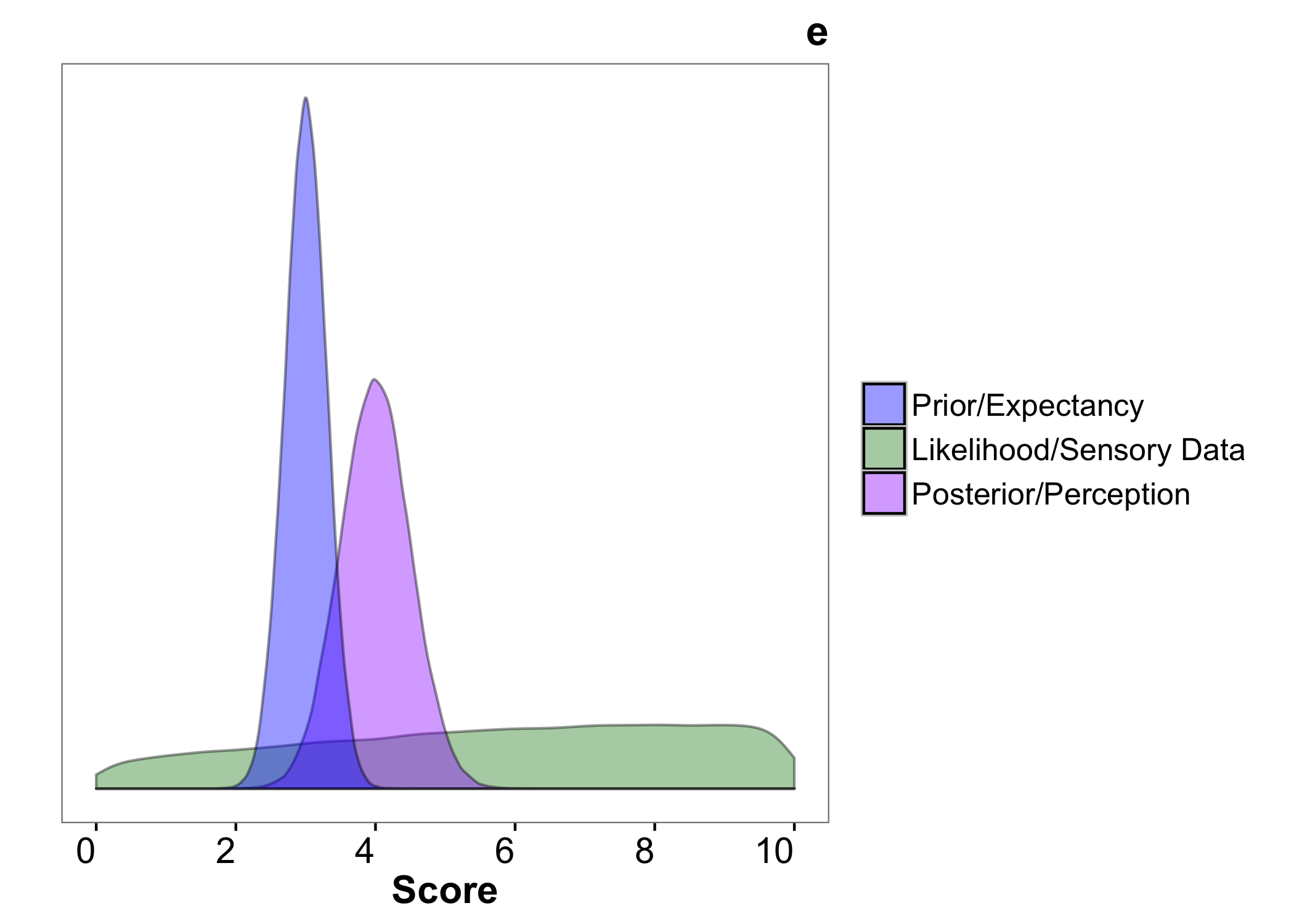
Now let us consider a stronger placebo effect. On this occasion there is no warning during the consent process that the cream could be a placebo. Furthermore during training participants have the cream applied on half the trials. When the cream is applied the experimenters surreptitiously turn down the shock level so that participants feel less pain on trials when the cream is applied. The following graph represents the test phase when the cream is applied but shock levels are increased to the same levels as during the no-cream trials in training (and the same levels as scenarios a, b, and c).



Because participants were not told that they *could* be given a placebo cream, *and* because they experienced a reduction in shock when the cream was applied during training, they are much more certain in their belief that the cream will reduce their pain. This is represented on figure (d) by a tall, narrow prior distribution. Thus though the shock level/sensory data is the same level as in (a), (b), and (c) there is a pronounced placebo effect, with the perceived pain being noticeably lower.

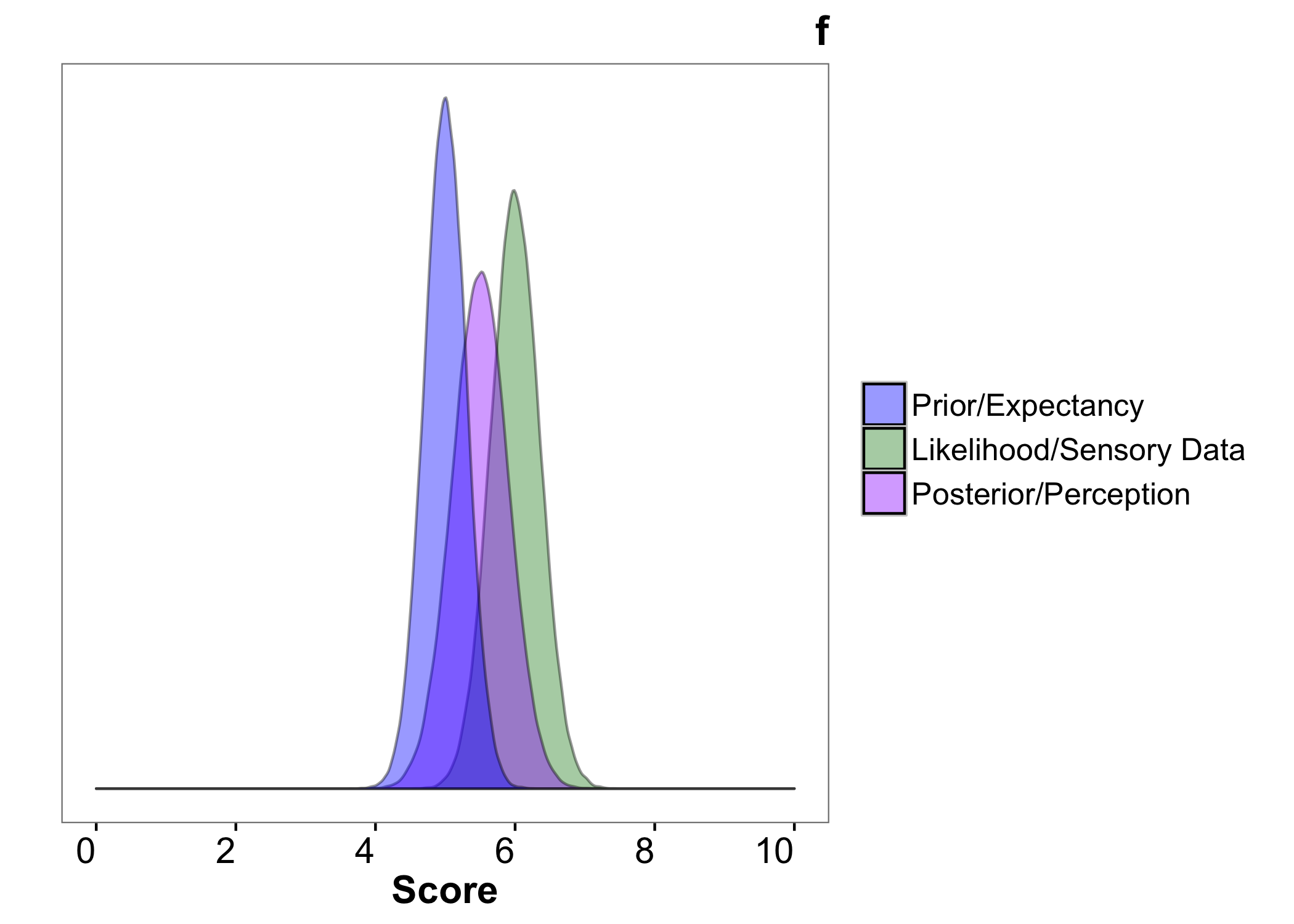
Bayesian models of perception say that sensory evidence has more weight when expectations are more uncertain, due to the increased attention on sensory information during uncertain conditions (Yu & Dayan, 2005). This has been applied to Bayesian models of the placebo effect which suggest that the higher the level of expectancy the greater will be the placebo effect. However Bayesian inference is an *integration* of prior information and current data. Yet to date Bayesian models have only considered the effect of uncertainty of prior information on the resulting sensation without considering the other source of potential uncertainty, the sensory data itself. Placebo effects have been observed across multiple sensory modalities and I suggest that there is a hierarchy of sensations, from more precise to less precise, less uncertain to more uncertain, that interacts with the uncertainty of the prior beliefs to form the final sensation. The first tier of the hierarchy will be filled by direct senses, in this order, vision, hearing, touch, smell and taste; the second tier by interoceptive sensations such as pain, nausea, temperature, fatigue, alertness; the third and final tier by affective sensations such as anxiety, sadness, irritability, tension. The more certain the prior and the less precise the sensory modality, the greater will be the influence of the prior on the final (i.e. posterior) perception. The prediction flowing from this model is that the higher the tier of the hierarchy the sensory modality belongs to the less susceptible it will be to expectancy effects generally. Let us apply this new version of Bayesian perception to a similar scenario that we have considered above, except for a different sensory modality.

Let us say that instead of pain induced by an electrical shock we are considering fatigue induced by a sleep deprivation procedure, and that instead of a placebo cream participants are given decaffeinated coffee without being told that there is a possibility of receiving a placebo. Let us also say that participants went through a training phase in the same lab where under the same sleep deprivation conditions they were given real coffee that lessened their fatigue. Let us also say that participants are asked to rate their fatigue immediately after the sleep-deprivation procedure rated it 8/10 on a fatigue scale. The prior in figure (e) is their expected level of fatigue when they consume their coffee, which they do not know is decaffeinated (i.e. placebo).

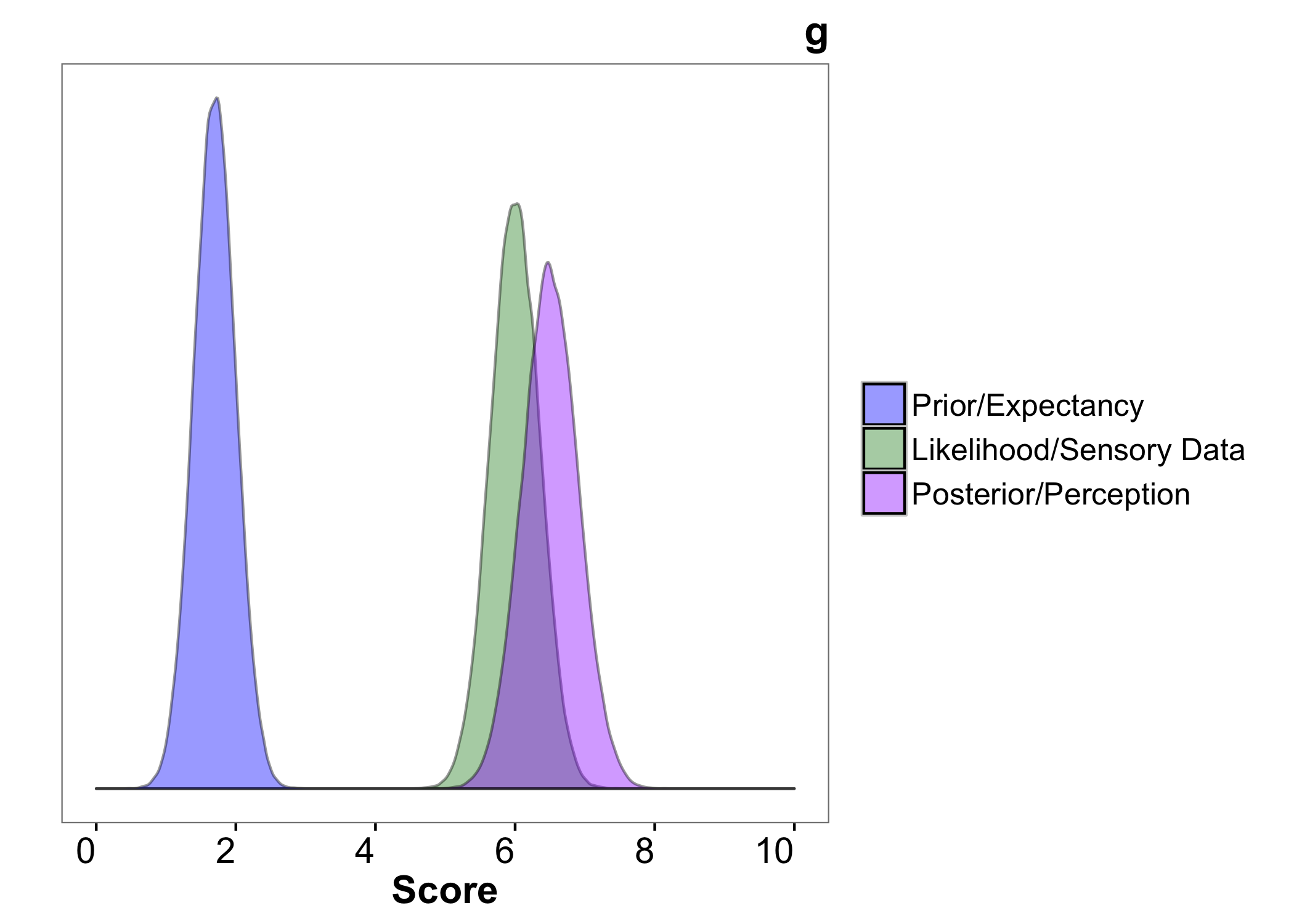


Now, like scenario (d) we have the situation where there is strong certainty that the treatment will lower the level of the outcome, but in this case the sensory modality of the outcome, fatigue, is *inherently* less precise than pain. The participant has no extra sleep nor any actual caffeine, therefore the distribution is still centred on a mode of 8/10. However because the sensory data comes from a vague modality, the distribution of the sensory data is wide and diffuse, with only a slightly higher certainty over 8/10 than any other rating on the scale. Because the precision of the sensory data distribution is low compared to the precision of the prior/expectancy distribution, the prior has a much greater influence on the final posterior perception even than it did in scenario (d) despite the fact that the priors are identical in both. Thus we see a much stronger placebo effect in (e) than in (d), due entirely to the differing properties of the sensory modalities in question, fatigue vs pain. Thus by incorporating *sensory* uncertainty as well as uncertainty of belief into the model we get a more nuanced view of how belief and sensory data might interact to produce placebo effects.

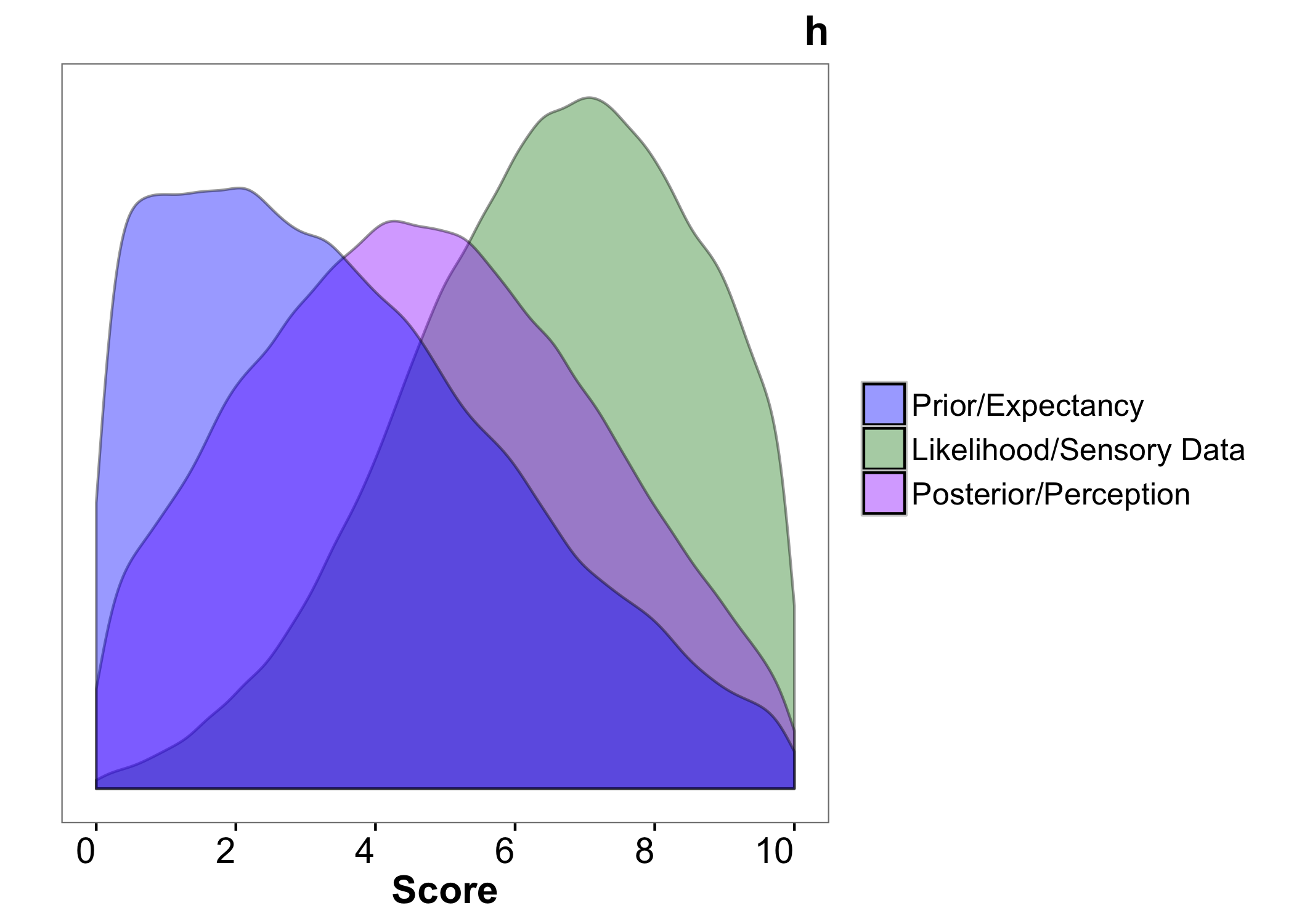
Other permutations could be admitted in this model. As mentioned the level of incongruence of the expected outcome with the sensory data (i.e. distance between the modes of the prior and the sensory data distribution) is as important as the level of certainty of each (i.e. width of the distributions). Thus we could have strong belief in an effect in a precise sensory domain but, so long as the level of incongruence between the expected outcome and the actual data is low there could be a placebo effect. An example is presented in figure (f); the estimation of the location of an auditory signal while wearing a blindfold. In this figure the abscissa represents location in an array, with 0 being far left and 10 being far right. According to the sensory hierarchy already discussed the sensory domain in question, hearing, is quite precise. If there is also a strong belief in where the signal will emanate from, say because it has come from that location on previous trials then we have a scenario with incongruent but precise beliefs and signals. If the location of the actual signal is close to the expected location then the final estimate of the location will be pulled slightly in the direction of the expected location, away from the actual location.



If on the other hand both sensory domains are precise but there is a high level of incongruence between the expected location of the signal and the actual signal then there will be no overlap in the distributions of each and the expected location may have no influence over the location. In fact, if we apply the assimilation-contrast model, it may be that the great divergence in expectation and actual location so violates expectations that a compensatory placebo effect takes place, where the final estimated location is dragged in the opposite direction to the expected effect. This situation is presented in figure (g), where we can see the final estimated location is to the right of the actual location of the signal, despite the expected location being to its left.



High incongruence need not always lead to contrast effects. If both expected levels of the outcome *and* the sensory modality are imprecise then placebo effects are still possible. Take the example presented in figure (h) concerning the effect of taking a placebo anti-depressant on a depressed individual who rated their depression prior to taking part in the study at 7 on a depression scale. Because emotional variables are low in the hierarchy, the distribution for the sensory data indicating that no change has taken place is diffuse and centred on a mode of 7. Let us say that the participant has a strong belief that the anti-depressant will greatly reduce their symptoms but has been warned at the outset of the study that there is a possibility they might receive a placebo. Therefore they have a weak expectation of a large reduction in symptoms represented by a wide distribution, but with a mode a long way from the original rating.



The model proposed here shares common features with existing Bayesian models of placebo effects. Firstly it emphasis the interaction between actual stimulus and prior beliefs and proposes that perception is an inferential process that integrates both. Secondly it incorporates uncertainty. The effect that beliefs have on the final perception depends on their level of certainty. Thirdly the model says that placebo effects are perceptual phenomena, caused by allocation of attention towards and away from bodily signals. The more certain the prior the less attention is paid to bodily symptoms and thus the more the final perception is shaped by expectations. The less certain the prior expectations the more attention is paid to bodily sensations and the less influence the prior expectations have over the final process. This view is in contrast to the neurobiological approach which states that placebo effects are caused by neurochemical mimicry of the effects induced by the expected drug.

The novel element to this model is that it incorporates the uncertainty of the sensory modality into the model as a determinant of the final sensation, in addition to the uncertainty of the belief, It states that expectancy manipulations in less precise sensory modalities will produce larger placebo effects than those in more precise. In addition, via incorporation of contrast effects, the model explains how placebos might fail to produce effects if the level of incongruence between expectancy and sensory data is too high.

Bayesian perceptual theories have several advantages over neurobiological theories. (1) perceptual theories do not require the discovery of a specific neurochemical, neuroarchitectonic or physical mechanism to explain placebo effects across each of the different perceptual domains in which placebo effects have been observed. Thus, provided the outcome measure is subjective and its perceptual domain interoceptive, mechanisms responsible for shifting attention are sufficient to explain most findings across the placebo literature. In fact even placebo effects for objective symptoms can be explained by the theory, provided they are ‘downstream’ correlates of psychological states or subject to some degree of willful control (e.g. heart rate, blood pressure, galvanic skin response, penile tumescence). (2) perceptual theories can account for desirable and undesirable placebo effects, even if they occur at the same time (Faasse, Cundy, Gamble, & Petrie, 2013; Shapiro et al., 1974), as long as the effects are in sensory modalities whose indices are interoceptive/subjective and thus are more vague and amenable to alteration by prior beliefs. (3) one of the model predictions is that level of certainty in beliefs will correlate with size of the placebo effect, thus explaining why placebo effects are more pronounced under deceptive than ambiguous instruction (Kirsch & Weixel, 1988). (4) to the extent that they all serve either to increase certainty in, and/or strength of the anticipated treatment effect, the model is also able to explain why factors such as the route of administration, color, taste, number and size of doses of placebo correlate with strength of the placebo effect (Buckalew & Ross, 1981). (5) The model also explains why placebo effects can be found in the healthy and the sick, since both are capable of diverting attention to and from bodily states. (6) the model explains why hidden interruption of an analgesic drug causes slower increase in pain than open interruption, and why hidden administration of a drug causes a slower decrease in pain than open administration (Benedetti, Maggi, et al., 2003). (7) the model is able to explain how placebo effects can be localised (Montgomery & Kirsch, 1997) or global (Amanzio & Benedetti, 1999) since attentional resources can be narrowed down to specific parts of the body or widened to global states. (8) The model is also able to explain why placebo effects extinguish over time (Yeung et al., 2014). The perceptual model frames the extinction of placebo effects as the gradual overcoming of data from prior beliefs by data from the senses. With reference to the graphs above this would represent a narrowing of the likelihood/sensory data distribution. (9) Finally, and most importantly, the perceptual shift model is able to explain why rodents’ conditioned responses to cues that signal the presence of drugs tend to be compensatory (i.e. the CR tends to act in the opposite direction to the UR) whereas humans’ subjective placebo responses are almost *always* in the same direction as the UR. This is because expectancies about the effects of a treatment can only ever be formed around effects that have been observed in the past. Perception of conditioned compensatory responses immediately prior to taking drugs are mostly overshadowed by the positive effect of the drug, therefore the attentional ‘overriding’ of sensory data by relatively certain expectations of an imminent effect *can only occur in the direction of the effect that has been observed in the past and is expected.* The same phenomenon may apply to rodents; however there are no subjective measures of expectancy in rodents. The implication of this is that, provided the perceptual domain being studied is imprecise enough, humans’ subjective reports of what they feel following a treatment can be independent of related objective physiological measures (Ehrman, Ternes, O'Brien, & McLellan, 1992; Lane & Phillips-Bute, 1998; Phillips-Bute & Lane, 1997).

The disadavantage of perceptual models is that they have trouble explaining placebo effects in variables that are not subjective. With placebo effects on objective measures that are heavily influenced by psychological variables such as blood pressure and heart rate (Kirsch & Rosadino, 1993; Kirsch & Weixel, 1988), penile tumescence (Briddell & Wilson, 1976) or bronchioconstriction (Butler & Steptoe, 1986) it is easy to suggest that these changes are due to attention-mediated changes in appraisals of current mental state. For example if, following being administered placebo alcohol, one has shifted one’s attention to one’s level of arousal and begun to search for sexual thoughts, the simple act of this search may engender sexual thoughts which cause sexual arousal and a concomitant increase in penile tumescence. However some placebo effects are not so closely tied to current mental state. For example de Craen et al. (1999) found that increasing the number of placebos administered per day sped the rate of healing of duodenal ulcers. However as discussed below (under ‘Mediation’) an attention-mediated drop in anxiety caused by a belief in having received effective medication could improve immune function and thus general health and rate of healing. The final set of findings that are difficult to reconcile with a purely perceptual account of placebo effects are those where placebo effects occur with outcomes that cannot even be perceived directly, such as respiratory depression (Benedetti et al., 1998). It should be pointed out however that pure expectancy theories cannot explain this either, other than by admitting that several placebo mechanisms may be necessary to explain the full array of placebo effects and that unconscious conditioning accounts (reviewed above) are necessary to explain such unconscious placebo effects. In fact is possible that conditioned placebo effects and perceptual shift may operate concurrently but independently of one another. This may explain how physiological and objective symptoms of caffeine withdrawal can differ widely in degree of severity, with participants reporting high subjective withdrawal symptoms following caffeine deprivation but only very low decrements in objective performance measures (Lane & Phillips-Bute, 1998; Phillips-Bute & Lane, 1997). Differing and independent sources of placebo effects may also help explain how individuals addicted to opiates experience significant changes in skin temperature, heart rate, respiration, and galvanic skin response after ‘cooking up’ an inert powder in a spoon yet *reported* no increase in subjective withdrawal symptoms (Ehrman et al., 1992), indicating a conditioned preparatory/compensatory response to drug related stimuli that nevertheless escaped participants’ awareness.

Rescorla (1988) recommended assessing the informational value of stimuli when considering learning phenomena. Thus it is worth assessing the clarity of the information individuals receive from a sense prior to conducting research into placebo effects in that sensory modality. The information-processing model of placebo effects discussed above extends the Bayesian Placebo model proposed by Buchel et al. (2014) and others by including consideration of the precision of the modality of the sensory data in addition to the precision of prior beliefs.

According to this model the more uncertain are prior beliefs the more attention will be paid to internal cues and the less likely or pronounced will be the placebo effect. For example a user of illegal drugs whose dealer regularly changes the potency of the drug they consume will be more vigilant to their interoceptive signals and thus more attuned to the true potency of the drug than a person who obtains their drug from a pharmacy or hospital dispensary. Thus according to the model placebo effects would be stronger in clinical settings. The prediction of this model is that the ambiguity of the sensory domain and the plausibility of the placebo will determine the strength of the placebo effect.

### Misattribution

Theories of misattribution are closely related to the Bayesian theories of perceptual shift outlined above in that processes are thought to be controlled by attention. Another way of expressing misattribution as a source of placebo effects might be ‘symptomatic overlap’. In simple terms this is mistakenly attributing the cause of a change in one’s symptoms to one source when in fact it comes from another. Misattribution occurs when the symptom profile of the active drug, for which the placebo is mistaken, overlap with symptoms caused either by another agent that would have occurred irrespective of the administration of the placebo such as a drug or virus or infection or bacteria, *or* with incidental, nonspecific, and ambiguous symptoms that occur regularly in everyday life (for reviews see Ross & Olson, 1981, and Barsky, Saintfort, Rogers, & Borus, 2002), such as headache, fatigue, insomnia, anxiety, depression nausea, diarrhea, and dizziness (Khosla, Bajaj, Sharma, & Mishra, 1992; Reidenberg, Lowenthal, & Sacks, 1968)[[2]](#footnote-2).

There are two possible mechanisms by which misattribution may work to alter symptoms. The first is a direct effect of expectancy. This occurs when the expected effects of the treatment or stimuli cause a change in mental state which *directly* alters one of the variables that are thought to be influenced by the treatment itself. For example expecting relief from depression or anxiety by taking an SSRI could easily make someone less sad or anxious. Similarly expecting insomnia could cause sleep difficulties. The affective processing system is largely agnostic to causation—depression and anxiety and their relief feel the same irrespective of what caused them—therefore if the symptom profile of the treatment overlap with symptoms caused by *expectation of the effects of the treatment* they will be easily conflated, both by participants and researchers. Misattribution of this sort is thought to be responsible for the increase in incidence of reported headaches and sleep disturbance near windfarms (Pedersen, 2011), much of the effects of antidepressants (Kirsch, 2014).

The second form of misattribution works via a variant of the perceptual shift mentioned in the previous section. Because the individual receiving the placebo is anticipating a change in certain symptoms, a confirmation bias is created, whereby changes in symptoms that overlap with the expected effects of the drug, even if they are caused by another source, are rendered more salient and thus become more likely to be noticed and/or reported than they would be had the individual not received the placebo (Green, 1964). It is thought that there are three processes by which this occurs. The first is that if no instruction is given to individuals given the placebo about what effects to expect, as is typical in many clinical trials, it creates a state of uncertainty which leads to an *increased* scrutiny of bodily sensation. Secondly this increased focus on interoceptive cues leads to mild and infrequent bodily sensations becoming more noticeable. Lastly the perceived sensations and any cognitive appraisals based on them (e.g. ‘I am sick’) induce negative emotions such as fear that in turn amplify the bodily sensations via processes that will be discussed below in the section ‘Mediation’ (A. J. Barsky, Goodson, Lane, & Cleary, 1988). These processes are collectively known as somatosensory amplification; which is the amplification of bodily sensations caused by increased attention to interoceptive cues. Another way of describing this phenomena is that expecting symptoms creates a perceptual bias which, via increased scrutiny of bodily symptoms, lowers the threshold for perceiving, and thus reporting, bodily symptoms. The extent to which this process occurs is influenced by personality characteristics of the individual such as hypochondriasis (Arthur J Barsky, Wyshak, & Klerman, 1990) and demographic characteristics such as age, profession, and gender (Doering et al., 2015; Green, 1964) but not the type of drug being taken (Doering et al., 2015).

One study amalgamated results across multiple clinical drugs trials in order to assess frequency and severity of reported symptoms both prior to and following administration of a course of non-specific placebos. Samples were well subjects (prisoners and employees at a medical school), residents in a retirement community, and patients in various medical practices across the United States (Green, 1964). Almost 4,000 participants in total were tested. It was found that, in the well subjects, placebo tended to increase the reported incidence of side effects symptoms that pre-existed, with the level of increase being dependent on the ‘dose’ of the placebo. In the aged patients, though the incidence of symptoms either remained the same or decreased, the complaints about the symptoms increased. The author reports: “In a number of instances the subjects themselves refused further treatment because of symptoms that inspection of the pretreatment records showed to have been present before the initiation of placebo therapy”. These observations strongly implicate attention as the factor responsible for the placebo-induced increase in reported symptoms: the placebo either caused an increase in reporting of symptoms participants were already experiencing with relative frequency, or increased the subjective aversiveness of the symptoms without increasing their incidence. The author suggests that the belief of having received medication focused the participants attention so that “some complaints given little or no attention are magnified to a degree where they become regarded as ‘side effects’ of the medication being given” (p. 264). Furthermore the fact that patients were studied before and after placebo and also eliminates mere observation by researchers and physicians as being responsible for the increase in reported symptoms.

It is important to note that perceptual shift and misattribution explanations of placebo effects are based on the assumption that the placebo does not cause a change in incidence or severity of the actual symptoms, but merely increases the likelihood of their being reported. Both processes are thought to be mediated by attention, prior beliefs, and the interaction between the two. While expectancy-induced neurobiological mimicry of the pharmacological profile of the expected drug has been discovered in placebo pain research, it is questionable whether such mechanisms will be discovered for the myriad of placebo effects in other sensory modalities. Nociception—placebo analgesia and hyperalgesia— is the sensory modality that has been by far the most researched. So it may be that the lack of discovery of equivalent processes to endorphin-mediated placebo analgesia and cholecystokinin-mediated placebo hyperalgesia is a result of lack of adequate funding. However until that funding is forthcoming, the attentional theories of placebo effects remain the most viable explanations, over and above intentional deception, for the findings of placebo effects across multiple sensory domains.

If on the other hand placebos are administered with deceptive instruction, according to the theory, certainty would be higher and thus less attention paid to bodily cues. Therefore, if the instructed effects of the drug were positive, it may result in reduction of reported symptoms (Kirsch & Weixel, 1988).

### Mediation

Mediation refers to the fact that some placebo responses may be mediated by change in a third variable. The most plausible mediating variables put forward as being responsible for observed placebo responses are emotional change and behavior change.

There is evidence that anxiety increases the subjective experience of pain (Evans, 1974). Patient improvement following administration of a placebo analgesic may therefore be brought about indirectly by the fact that the patient expects to feel better and that this causes their anxiety to be reduced, which in turn causes their subjective experience of pain to be reduced (Benedetti & Amanzio, 1997; Staats, Hekmat, & Staats, 1998). The same rationale applies for increases in anxiety and placebo *hyper*algesia. A second way that emotional change might bring about placebo effects is through somatisation. Somatisation refers to the process whereby objectively measurable changes in bodily effects such as compromised immune system function (Maier, Watkins, & Fleshner, 1994) are brought about *directly* by changes in mental states such as stress, anxiety and depression. Therefore the administration of a placebo might cause expectation of pain relief which reduces anxiety. The reduced anxiety causes an improvement in immune system function which aids the healing process and reduces pain.

The problem with the theory that placebo effects are merely ‘downstream’ results of changes in emotional state in response to expected future treatment effects is that: (1) global emotional changes cannot account for localised placebo analgesia in one location on the skin but not another (Benedetti et al., 1999; Montgomery & Kirsch, 1996), (2) the theory cannot account for the simultaneous experience of positive and negative placebo effects (Faasse et al., 2013) because this would entail simultaneously feeling high and low anxiety, (3) the theory cannot account for positive placebo effects in healthy individuals whose immune system is presumably at ceiling levels of function and therefore could not be responsible for any *changes* in systems whose improvement could be induced by improvement in immune system (e.g. pain). However the mere observation that mediation by emotion is not responsible for all placebo effects does not necessarily mean that it is not involved in some. Evidence suggest a place for emotions as mediator of some placebo effects. Certainly placebo effects for affective variables such as anxiety, irritability, and tension could easily be directly caused by expectations of symptoms relief. In fact it is thought by some that the response to anti-depressant or anti-anxiety medication is *mostly* caused by the improvement in mood caused by anticipation of getting better.

Another mediating factor is when the placebo causes behaviour to change and this behaviour brings about change in the relevant domain. For example a belief that one will recover from an illness could improve mood and initiate socializing. Increased social support and decreased loneliness could lead to lower stress and depression, which improves immune function and causes an improvement in health. Another example is that anticipated improvement in depressive or anxiety symptoms following administration of a placebo SSRI could initiate exercise which causes an improvement in immune function and then overall health. These are both examples of how expectancy, emotional change, and behaviour change might combine to cause in improvement in objectively measurable symptoms following administration of a placebo (Stewart-Williams, 2004).

The effects of mediating variables can easily be misattributed to the direct effects of the treatment by participants (and researchers), especially if the expected effects of the treatment/placebo match those elicited by the mediating variables. This misattribution then confirms appraisals on the part of participants of having received the treatment, which then elicit the type of somatosensory amplification and perceptual shift effects discussed in the previous section.

## Problems of Definition: Dualism and ‘Real’ Change

The sources of disagreement concerning the likely mechanism behind placebo effects for subjective variables are based on lack of a clear definition of the criteria for what constitutes ‘real’ change. In medical research there is a clear division between physiological variables (changes in blood pressure, heart rate, immune function, tissue damage etc), which can be observed directly, and psychological variables, which cannot. Thus in medical research there is some notional difference between objective and subjective symptoms, between ‘real’ symptoms and bias. In psychology however there is no such clear division. Psychological variables’ existence can only ever be inferred. While there are some objectively measurable variables whose movements are known to correlate with the latent psychological states (e.g. blood pressure, heart rate, heart-rate variability, changes in cerebral blood flow, changes in electrical activity) the precision of these measurements is still quite poor and often change in these variables can be potentially caused by multiple sources. Moreover even at their most precise these measures can only ever be indirect representations of the underlying mental states. Thus the reliability of objective measurements of psychological variables is open to question. Despite this fact, in placebo research and theory there is a tendency to demarcate placebo responses into two categories: change in responding brought about by ‘real’ change, and change in responding brought about by some form of bias. In many researchers there seems to be a reluctance to admit the possibility that certain placebo effects could be brought about by a change in attitude to a stimulus rather than a change in some actual bodily system, as if the former were a less legitimate form of psychological phenomenon and not worthy of study. This tendency to favour one form of placebo response over another is ironic given the routine observation in the first paragraph of most placebo manuscripts, that the placebo effect has traditionally viewed by the medical community as a thing to be ‘controlled out’. With his immediacy hypothesis Kirsch certainly takes the most extreme view, but the attitude is relatively endemic. Kirsch states that in any non-dualist account of psychology, all subjective states have a corresponding physiological state, called the ‘mind-body identity assumption’). The implication of this non-dualist approach according to Kirsch are that all changes in psychological state are accompanied by a physiological change. The problem with Kirsch’s account is that he takes non-dualism too far. The refutation of dualism was a necessary philosophical enterprise in order to refute the idea that the mind was a vessel for the eternal soul and was separate from the body. However Kirsch takes it to the opposite extreme by obfuscating the difference between systems in the brain and body. Clearly as he asserts thought of any kind is both made possible by and affects the movement of neurons within the brain, an unarguably physiological process. But Kirsch’s immediacy hypothesis neglects the fact that different systems within the organism perform different functions. Pain is caused by our brain’s receiving signals from nerves in the peripheral nervous system that sense inflammation or tissue damage. Reduction of pain can be caused either by the reduction of the source of the signals (e.g. reduction in inflammation by healing), or by attenuation of the pain signals via ingestion of analgesic drugs or release of endogenous chemicals such as endorphins. To talk of integrated systems in this way is not equivalent to dualism. Kirsch’s immediacy hypothesis talks about change in psychology being accompanied by a corresponding change in physiology but fails to specify what physiological systems he is talking about, instead insinuating that any talk of physiology being separate from psychology is dualism. If he is merely saying that thought is caused by the movement of electrons and protons in the brain then this is of course true but fails to explain placebo analgesia (which would seem to imply that thinking of pain reduction and pain reduction are synonymous). If on the other hand he is talking about release of endorphins this is another matter, but he suggests this is not the ‘unmediated’ change he is talking about (see Kirsch, 1999). It is unlikely he is asserting that thought alone can reduce tissue damage and inflammation. Thus Kirsch’s immediacy hypothesis needs reworking.

A great deal of the problems with theories of placebo effects centers around problems with definition of the criteria by which we define ‘real’ change: change in source or signal? Direct change in the source of pain or fatigue, (i.e. change unmediated by behavior which contributes to acceleration of healing or reduction of fatigue), by thought alone is unlikely. Direct change in signal via thought alone is more likely. According to the two principle theories discussed above, change in signal can happen mechanistically via the release of chemicals that act on pain signals (i.e. opiates) *or* it can come about via perceptual change brought about by attention-mediated inferential processes. That this latter possibility might explain placebo effects does not make these effects less ‘real’ in any sense, unless the criteria by which we define real change is a change in the source of the pain, in which case even endorphin-mediated analgesia is not real. My contention is that expectancy-induced change in the perception of pain brought about by a change in perceptual inference is real in the same sense as a change brought about by the release of endogenous opiates, or cannabinoids, or CCK, or dopamine. Like change in perception brought about by endogenous analgesic, change in perception brought about by change in perceptual inference affects our *appraisal of the signal* but does not affect *the source of the signal*.

## Summary

The placebo effect is a complex psychophysiological phenomenon. In all likelihood placebo effects come from many different sources, some of which have been discussed. The preeminent theory is that placebo effects are caused by the expectancies individuals hold concerning the likely effects of the treatment they have been given. These expectancies can be induced by verbal instruction alone or via a conditioning procedure or by both instruction and conditioning. The precise mechanisms by which simple beliefs are able to induce change in different subjective symptoms is still unclear. Some like Irving Kirsch suggest that expectancies are able to directly influence the systems involved in the placebo response, however these theories do not propose any definitive mechanism by which this might occur. There are also neurobiological theories asserting that placebo effects are caused by a neurophysiological response that mimics the effect of the drug for which the placebo is mistaken. There are also theories that suggest that placebo effects represent some sort of response bias: either intentional deception, perceptual shift, misattribution or mediation. Irrespective of whether they result from objectively observable physiological changes or from response bias, all placebo responses come about because of changes in expectancies. The placebo effect is a complex psychophysiological phenomenon. While some placebo responses may be intentional deception on the part of participants it is unlikely that this accounts for the full range of placebo phenomenon. Whether it be subjective or objectively measurable effects it is clear that placebo effects are elicited primarily by expectancies, learned over time and repeated observations, that certain treatments will elicit certain effects. However precisely what mechanisms are responsible for placebo effects is still uncertain. What is certain is that the debate over why and how placebo effects occur will continue to preoccupy researchers in the medical and life sciences for many years to come.

1. In fact the original meaning of the latin word placebo is ‘I shall please’. [↑](#footnote-ref-1)
2. The effects listed here are all negative placebo effect, but positive placebo effects such as an increase in alertness or a lessening of a headache or stomach pain could be due to spontaneous remission, and this could be misattributed to the action of the drug/placebo. [↑](#footnote-ref-2)