The Price of Pain and the Value of Suffering

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Abstract

Estimating the financial value of pain informs issues as diverse as the market price of analgesics, the cost-effectiveness of clinical treatments, compensation for injury, and the response to public hazards. Such costs are assumed to reflect a stable trade-off between relief of discomfort and money. Here, using an auction-based health market experiment, we show the price people pay for relief of pain is strongly determined by the local context of the market, determined either by recent intensities of pain, or their immediately disposable income, but not overall wealth. The absence of a stable valuation metric suggests that the dynamic behaviour of health markets is not predictable from the static behaviour of individuals. We conclude that the results follow the dynamics of habit formation models of economic theory, and as such, the study provides the first scientific basis for this type of preference modelling.

Introduction

Attaching economic value to aversive states and clinical symptoms is central to health economics. In most cases, the cost of relieving suffering must somehow be balanced against the amount of suffering relieved. Economic theories of valuation generally assume that the prices of such commodities are derived from genuine fundamental values. The assumption is that people have robust endogenous preferences which allow a trade-off between goods, including analgesics, and money (Shafir & LeBoeuf, 2002). However, the validity of this assumption, and its applicability to health products, is increasingly questioned, and contrasts with an emerging alternative possibility that preferences are labile, and predictably so. This lack of stable underlying values raises the possibility that in some markets consumers may, as Oscar Wilde, remarked about cynics, "know the price of everything and the value of nothing."

Indeed, psychological experiments suggest that sensory judgments of magnitudes and probabilities are made relative to other recently experienced events, and are not bound to an absolute scale (Laming, 1997; Stewart, Brown, & Chater, 2005). Hypothetical willingness-to-pay-to-avoid prices are typically biased towards price anchors (Ariely, Loewenstein, & Prelec, 2003). This resonates with the idea that an option in a choice set may change the way another option is judged and, more broadly, evokes the idea that preferences are *constructed* afresh, rather than *revealed,* in the light of the salient options in each new situation (Slovic, 1995).

However, this conclusion might be premature, because it is conceivable that people might not need to know the value of something if they already know its price. Existing studies have not tested preference formation at its very root, where prior price information is not available as, for example, when people experience stimuli or events for very first time and must pay to obtain or avoid this experience in the future.[1] Indeed, such scenario is a close approximation to consumer behaviour in many health contexts where pain or symptoms of illness are likely to represent new events. Observing relativistic effects in this context would imply that the price consumers pay (e.g., for health) may be substantially determined by current or recent experiences, rather than stable underlying values, posing real challenges for health economics.

We designed an experimental market in which healthy participants could choose to pay money to avoid a painful electrical stimulus. Our use of electrical shocks is based on the idea that they are not generally encountered in daily life (cannot be related to any existing commodity or price), and hence prior price-related information cannot be brought to bear. Additionally, a painful shock is evaluated and 'consumed' immediately, is consistently judged as aversive across participants, and is largely resistant to habituation over the course of an experiment. Finally, the underlying neurophysiology of shock induced pain is well-understood, and importantly the affective properties (hedonic unpleasantness) of pain are known to be dissociable from sensory properties (intensity, location, etc.) (Singer *et al*., 2004). Note also that phasic pain (that varies over short time intervals) is used widely in laboratory pain research in both animals and humans, with the very direct aim at applying results to chronic pain (McMahon & Koltzenburg, 2005). The vast majority of research into chronic (e.g., cancer) pain (humans and animals) is based on tests of phasic noxious stimuli, but not because people do not recognise the difference between the two (quite the opposite), rather there are numerous methodological and ethical reasons against trying laboratory studies of chronic misery.

[1]For example, Boyce et al. (1992) asked people to value a houseplant (Norfolk pine with a retail value of $6) by offering willingness-to-pay to buy the tree, or willingness-to-accept to sell it, otherwise the experimenter was going to kill it. In this design, the price anchor was the existing retail price. The participants were not told the price, but they could have guessed it or known it in advance. Also, such trees are common commodity with many substitutes in the market.

In the experiment, participants received a single electrical stimulus and were then asked to decide how much they were willing to pay, from an initial monetary endowment for that trial, to avoid fifteen further shocks. If the price offer was more than a randomly determined market price, avoidance was ‘bought’ at the market price. Otherwise the endowment was kept and all fifteen shocks had to be endured. This design is analogous to buying pain relief in a computerised ‘second price’ auction (Becker, DeGroot, & Marshack, 1964), and has the characteristic that the rational strategy is to reveal ones’ true preferences. All of this was carefully explained to, and practiced by, each participant. There were 60 such trials in total where we also varied both shock intensity and the monetary endowment. Unbeknown to the participant, only 3 pain levels were actually used, namely low, medium and high with the pain levels grouped into blocks (of 10), such that the different levels co-existed in pairs (Low-Medium, Medium-High, Low-High) (see Figure 1). Finally, in one experimental group the endowment for each trial was 40 pence (£0.40), and for second experimental group of participants it was 80 pence, with participants randomly assigned to either group.

Methods

Participants. Thirty-four students from the University of London participated in the experiment. Approximately half were undergraduates, the rest were graduate students. Participants were randomly assigned to two experimental conditions. Each session lasted an average of two hours and each participant was awarded between £20 and £40 at the end of his session depending on her decisions as described below. Each individual participated at a separate time, and thus during each session only one participant was present. Sessions were conducted at the Wellcome Trust Centre for Neuroimaging, UCL, UK. All participants gave full informed consent before the experiment, in which they knew they would be receiving electric shocks and money on a probabilistic basis. The study was approved by The National Hospital for Neurology and Neurosurgery and Institute of Neurology joint ethics committee

Design. The sequence of activity within each trial of the training and experimental session is illustrated in Figure 1, which also shows an example of the displays that appeared on participants' screens during a typical trial. Our experiment had the following design characteristics.

a) Trial-based payment. On each trial, the participant is given a fixed endowment amount to spend on analgesia, which was not transferable to the next trial. Whatever was left from each trial is kept in the participant's pocket and the total payment for participation in the experiment is based on the accumulated money over all experimental trials (i.e., the money not spent on pain relief).

b) Willingness-to-Pay method. On each trial, the participant experienced one pulse of the electric shock. Thus, we provided the participants with a sample of the experience before they made subsequent decisions. Consequently, they entered the pricing phase of the experiment with full information about the experience they are evaluating. Next, participants had to state what is the maximum amount that he/she was willing to pay in order to avoid 15 pulses of the same shock intensity/magnitude. An offer was marked as a location on a visual scale, using a cursor operated by two keys on the keyboard, one to move it to the left and another to the right. On each trial the initial position of the cursor was randomly located on the scale. The process then continued to determine the market price.

c) Auction-based valuation. After the participant stated his/her maximum value, we used a second-price auction design (a standard incentive-compatible preference elicitation procedure proposed by Becker, Degroot, and Marschak (1964), in order to determine how much the participant had to pay. Thus, on each trial the computer would randomly pick a price from a uniform distribution ranging from 0p to 40p, or 0p to 80p, depending on the condition. The distribution was displayed on the screen in the form of a roulette wheel. If the computer's price was higher than the participant's price, the participant would experience the pain. If the computer's price was lower than the participant's price, the participant would pay this (computer generated) price and avoid the pain. We informed the participants that the spinning wheel ('wheel-of-fortune') determines the market price completely randomly, and therefore, the market price does not depend on the intensity of the electric shock, and does not depend on the offered price. Participants were told that this procedure ensures that the best strategy is to pick the maximum price they would be willing to pay in order to avoid the pain, not a few pennies more and not a few pennies less. We used the following argument to justify this claim: "Thus, it is in your best interest to offer a number that accurately reflects how you value the pain from the electric shock. If you write down a number that is higher than your personal valuation of the pain, then you may end up paying more than you feel it is worth to avoid the shocks. On the other hand, if you write down a number that is lower than your personal valuation of the pain, then you may end up suffering the pain, even though you would have been willing to pay a price to avoid it. Therefore, there is no 'right' or 'wrong' value to enter on the offer screen; rather it is a matter of offering a value which truly reflects your own valuation of the pain from the electric shock."

Procedure. Each session consisted of three parts, a thresholding procedure, a training session of 5 rounds without payment, and an experimental session consisting of a series of 60 trials for real money. In each trial of the training and experimental session, participants received one or more electric shocks. The order of stimuli (shocks) was randomized individually for each participant. Shocks were delivered using a Digitimer DS3 electrical stimulator through silver chloride surface electrodes placed 2–4 cm apart on the dorsum of the left hand. Each shock consisted of a 1 second duration train of monophasic pulses of 10ms duration at 10Hz. During their session, individuals were sitting in front of a computer, observed a computer screen, and used two key on the keyboard to submit their decisions. The software package, COGENT 2000 (FIL, UCL), was used for stimulus presentation and response acquisition. At the end of the task, participants were fully debriefed and thanked for their participation, and given an opportunity to make any comments.

At the beginning of the session, following consent from each participant, he/she underwent a standard pain *thresholding procedure*. The purpose of this procedure was to control for heterogeneity of skin resistance between participants and to administer a range of potentially painful stimuli in an ethical manner. In particular, to determine the pain levels to use in the task, as in previous experiments (Seymour *et al*., 2004, 2005), participants experienced incremental intensities of current, during which the give simple visual analogue ratings on a 0-10 scale (with the ends of the scale anchored with the verbal desriptors as follows: '0' = 'not painful; and 10 = 'worst imaginable pain', with participants effectively rating along a continuous monotonic scale between these points). This is done several times, starting off with very mild intensities, to familiarize participants with the set-up. When tolerance is reached, we then estimate the current-to-rating response curve, by statistically fitting a weibull (sigmoid) function, to a short series of randomised sub-tolerance probe stimuli. The current intensities that relate to three levels of pain (mild 4/10, moderate 6/10, strong 8/10) were estimated from this function, which corresponded to the three shock levels (Low, Medium, and High) used in the experiment. Although the stimulation is necessarily within the painful range, electrical stimulation is safe, and does not cause any significant side-effects. It has been used extensively in the past in human experiments, and many times in our lab. Note that general variation in subjective ratings of electrical (and indeed other forms of) pain are easily sufficient to mask the fact that the pain fell into three levels, and, as confirmed by post-experiment questioning, participants assumed an even distribution.

Results

Valuations. We observed higher price offers for medium pain relief when experienced in a sequence of trials in which there were many low pain trials (Low-Medium block), compared to when the same pain was experienced in a sequence in which there were many high pain trials (Medium-High block). That is, participants were willing to pay more to avoid the *same* pain when that pain was *relatively* more painful, rather than relatively less painful, compared to recent trials. This effect was evident for both the 40p endowment condition, $t(17) = 5.68$, $p < 0.001$, and the 80p endowment condition, $t(17) = 3.82$, $p = 0.001$. Thus, what we observed was consistent with a relative valuation of medium over high or low intensity stimuli, as illustrated in Figure 2*a* and Figure 2*b*.

To further explore this relativity in valuation, we tested for a rescaling as a function of endowment (40p vs. 80p) between groups. We found that higher offers were given when high endowment was received and vice versa (note price scale on *y*-axis in Figure 2*a*). For example, in comparison to the 40p endowment group, there were significantly higher price offers for *medium* shocks in both the Low-Medium, $t(34) = 4.05$, $p < 0.001$, and Medium-High, $t(34) = 2.79$, $p = 0.01$, contexts in the 80p endowment group. To a good approximation, if people have twice as much endowment in a trial, they are willing to pay twice as much to avoid the same pain. Thus, the ‘exchange rate’ between money and pain is extremely flexible with respect to the endowment.

Figure 2*c* plots the change in difference between the average price offer for medium pain in the Low-Medium and Medium-High blocks. As expected, in each type of block, the difference between prices is initially small, but diverges as a function of experience within the block: the positive slope of the regression line was significant for both the low 40p ($b = 0.96$, $t(9) = 2.86$, $p = 0.02$) and 80p ($b = 1.73$, $t(9) = 5.41$, $p = 0.001$) endowment conditions.

To frame our results within economic theory (in terms of what is known as *comparative statics*), we next plotted the estimated consumer demand curves for pain relief (presented in Figure 3*a*-*c*). To make the data relevant to chronically experienced pain, and also to economic theories of consumption, we included only the trials which followed experienced long (15 shocks) long pain (not just the single example shocks) on the previous trial (i.e., we included only trials following consumed pain). These curves are constructed directly from our data, and address two questions: the first is related to how much pain relief would have been bought by our participants, at different prices, given their stated willingness to pay, and the second question is related to the consequences of increases in income. Presuming medication is a ‘normal good’, the standard assumptions in health economics is that demand functions are downward sloping and shift rightward with income (in our case, this is the endowment: 40p vs. 80p). In this respect, our findings are in accordance with these assumptions, as shown in Figure 3. However, note that finding income effects in our laboratory setting is still puzzling, for the income received during the experiment is tiny relative to the participant’s total income (in-lab plus outside money). This finding is, however, well known---a large literature in experimental economics has been spent on studying the so called *adaptive encoding* phenomena (also known as *narrow framing*), for instance in the context of risk aversion (e.g., Barberis, Huang, & Thaler, 2006): economic problems are not put in their wider context, but only within the narrow situation at hand, because the brain’s limited resources are allocated so as to discriminate better among more likely (i.e., recent) outcomes (Tobler, Fiorillo, & Schultz, 2005). Therefore, we conclude that our income effect is yet more evidence for adaptive encoding.

There was also a significantly higher potential demand for medium pain (Figure 3*b*) when paired with low rather than high pain, which applies both for both the 40p, $X^2(7) = 24.7$, $p < 0.001$, and 80p cash endowments, $X^2(15) = 32.7$, $p = 0.01$. These results imply that the demand to avoid the medium pain was substantially affected by whether the previous pain was higher or lower (as in Figure 2), which suggests that consumer demand estimated from real markets do not necessarily always reveal stable underlying preferences (assumed by some normative decision theories). These effects can be explained by looking at how economics deals with problems involving *dynamics*: changes in prices and quantities over time (as opposite to the comparative statics mentioned earlier). The conclusions depend crucially on how demand is modelled. Since the early 1970s, habit has become an important component of modelling preferences. Such models assume that the overall level of satisfaction derived from a given level of consumption depends, not only on the current consumption level itself, but also on how it compares to some benchmark reference level, which is an internal criterion based on the individual's own past consumption levels (Osborn, 1988). A simple approach is to model habit by making the utility of time t consumption $c(t)$ depend on past consumption $c(t\text{-}1)$: $utility = u(c(t)\text{-}c(t\text{-}1))$, where u is some standard, monotonically increasing utility function which is strictly concave (meaning that the slope of the curve decreases as its argument, the change in consumption $c(t)\text{-}c(t\text{-}1)$, increases). That is, utility depends on the *change* in consumption over the last period. Such utility function based on habit can explain our results in the following way.

In order to show how habit formation models predict our results, let c denote consumption without pain (when buying oneself out of pain); and let c_l, c_m and c_h denote consumption under low, medium and high pain respectively. Obviously, consumption is highest under c and lowest under c_h and hence $c_h < c_m < c_l < c$. First consider Figure 3b. Keeping income the same, we need to determine whether the value of (i) getting out of medium pain when just experiencing low pain (and hence, c_l) is higher than that of (ii) getting out of medium pain when just experiencing high pain (and hence, c_h). Mathematically (following the habit model above), the former value equals $u(c - c_l) - u(c_m - c_l)$; the latter equals $u(c - c_h) - u(c_m - c_h)$. Now, since algebraically $c_m - c_l < c_m - c_h$ and $(c - c_l) - (c_m - c_l) = (c - c_h) - (c_m - c_h)$ and the utility function (u) is strictly concave, it follows that (i) is more valuable than (ii), and hence, the demand curve for avoiding medium pain when experiencing low pain is higher than that of avoiding medium pain when experiencing high pain. The demand curves in Figure 3b do satisfy this as the "vs. low" curve lie to the right of the "vs. high" curve for both 40p and 80p endowments, which is what the theory predicts. An analogous analysis predicts that the demand curves for low pain and high pain (in Figures 3a and 3c) should follow similar pattern: for low pain, the "vs. medium" curves should be to right of the "vs. high" curves as they indeed are in Figure 3a; and similarly for high pain, the “vs. low” curve should be to the right of the “vs. medium” one as is indeed the case in Figure 3c. Note also that the gradual increase in the difference between the offer prices (Low-Medium vs. Medium-High) in Figure 2c is consistent with habit formation (which also happens gradually), because, as the demand curve analysis demonstrated, avoiding medium pain in the context of low pain is more valuable than in the high pain context. In summary, the demand curve analysis presented here clearly supports the habit based interpretation of the overall results presented in this article.

Discussion

The impact of cash endowment magnitude on each trial is consistent with the idea that people will spend roughly a constant fraction of their experimental income on pain relief. However, this behaviour implies that people cannot integrate their behaviour in the experiment with their finances outside the experiment. After all, whatever the experimental conditions, the value of money received in the experiment has the same value, when spent later outside the experimental setting. Nevertheless, to provide a tighter control for such budget issues, we conducted a second experiment using a within-participant design where we made the 40p-80p difference vary randomly between trials for the same participants (in all other aspects the design was identical to the original experiment). This second experiment replicated all our original results and thus confirmed our paradoxical result that the ‘exchange rate' between pain and money varies dramatically over a time frame of minutes for the same participant, as they shift from one block of trials to another,[2] which is yet more evidence for adaptive encoding (narrow framing) in decision making.

A key implication of our results is that the assessment of pain, and demand for pain relief, are almost completely relative to the experience of pain in the recent past, and the available cash-in-hand for that trial. Participants were willing to pay a constant fraction of the money available on each trial, even if the monetary sums they are paying differ by a factor of up to two. If people do not have well-defined 'fundamental values' for subjective experiences such as pain, this suggests that willingness to pay, or to avoid, goods for which there is an existing market (e.g., cups of coffee, theatre tickets) may be driven primarily by knowledge of market prices, rather than by reference to some underlying fundamental values. People may indeed know the price of everything but the value of nothing.

The absence of a stable valuation metric suggests also that the dynamic behaviour of health markets is not predictable from the static behaviour of individuals. We found our findings to be consistent with, and follow the dynamics of, economic models of habit formation. Note that origins of habit models can be traced as far back as Smith (1759) and Veblen (1899), while Duesenberry (1949) provided this idea with micro-economic foundations.[3] Effects of habit can be seen even at the macro-economic level---where the compensation for risk has remained unchanged in the Western world despite a huge increase in aggregate wealth (Abel, 1990; see also Carroll, Overland, & Weil, 2000, for evidence on the effects of habit on savings and economic growth). More recently, Fuhrer (2000) found that 80% of the effect on consumption utility should be attached to past consumption, which

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[2]Full description of these results is available upon request.

[3]The second another main type of reference consumption is based on external criterion expressed in terms of the past consumption of some outside reference group, typically the average consumption of the overall economy, which is often referred to as "catching up with the Joneses".

rejects the hypothesis of time separable preferences. There is no much documented experimental work on habit formation in health economics, however. As such, the findings of this article are providing the first solid experimental evidence in favour of introducing habit in preference modelling. Our habit-based analysis also suggests that principles underlying pain judgments may be based on relative judgments unlike other judgment models like the range-frequency theory (Parducci, 1965, 1995), which assume long-term representations.

Our results do not necessarily imply that the brain does not have stable representations of pain, but they do suggest that it cannot readily translate such representations into monetary terms. However, although the neurophysiological basis of aversive valuation is complex (Dayan & Seymour, 2008), there is evidence that such relativistic effects may indeed exist at an underlying biological level. Neurophysiological recordings in both monkeys and humans both have shown evidence of relative reward coding in neural substrates (for instance, via dopamine projections to the striatum and the orbitofrontal cortex) strongly implicated in simple choice behaviour (Nieuwenhuis *et al.*, 2005; Tobler, Fiorillo, & Schultz, 2005; Tremblay & Schultz, 1999), suggesting that value relativity may exist at a more fundamental level in the brain.

Explicit judgments concerning pain, and other subjective experiences, are typically expressed in complex social and economic contexts. This is the case, firstly, when we are forced to make abstract comparisons between experienced or imagined primary affective states and secondary rewarding ones, such as money. Furthermore, a particular difficulty in equating such diverse quantities to control purchasing behaviour is generated by the fact that health products are naturally inhibitory, in that one pays to avoid a certain aversive symptom, rather than to receive a positive good. That the products of effective health purchase embody the positively valenced property of relief has interesting parallels with the phenomenon of avoidance studied in animal learning theory, in which states that are associated with omission or termination of otherwise aversive events acquire, through inhibitory processes, rewarding valence (Dinsmoor, 2001; Rescorla, 1969; Morris, 1975; Seymour *et al*., 2005; Weisman & Litner, 1969;). Whereas increasing experience might mitigate this, it cannot easily do so for products which buy relief for never-experienced symptoms, a central "commodity" in modern preventative healthcare markets.

Explicit judgements are also required when economists and policy makers quantify adverse clinical states, to inform decisions regarding pricing strategy, investment in research and cost-effectiveness of treatments. Pain in particular is major public health issue, not least given the fact that approximately 20% of the general population suffer from clinically significant pain (Eriksen *et al*., 2003; Macfarlane, Jones, & McBeth, 2005; NFO World Group, 2007), leading to a global annual cost of analgesics of £40 billion. Importantly, pain rarely occurs in isolation, and is usually being experienced in the general symptomatic and temporal context of an illness. Thus, our findings on the structure of human value representations, and specifically their susceptibility to relativistic judgement biases shaped by context, is likely to have substantial economic consequences. Future research might usefully explore the stability of valuation for other clinical symptoms, and the impact of knowledge of other people's valuations, which may mediate an equally important role in dynamic healthcare markets.

References

Abel, A. (1990). Asset prices under habit formation and catching up with the joneses. *American Economic Review*, *80*, 38-42.

Ariely, D., Loewenstein, G., & Prelec, D. (2003). Coherent arbitrariness: Stable demand curves without stable preferences. *Quarterly Journal of Economics*, *118*, 73-105.

Barberis, N., Huang, M., & Thaler, R. H. (2006). Individual preferences, monetary gambles, and stock market participation: A case for narrow framing. *American Economic Review*, *96*, 1069-1090.

Becker, G. M., DeGroot, M. H., & Marschak, J. (1964). Measuring utility by a single-response sequential method. *Behavioral Science*, *9*, 226-232.

Boyce, R. R., Brown, T. C., McClelland, G. H., Peterson, G. L., & Schulze, W. D. (1992). An experimental examination of intrinsic value as source of the WTA–WTP disparity. *American Economic Review*, *82*, 110–137.

Carroll, C. D., Overland, J. R., & Weil, D. N. (2000). Saving and growth with habit formation. *American Economic Review*, *90*, 341-355.

Dayan, P., & Seymour, B. (2008). Value and actions in aversion. In: P. W. Glimcher, C. F. Camerer, E. Fehr & R. A. Poldrack (Eds.), *Neuroeconomics: Decision making and the brain*. London, UK: Elsevier.

Dinsmoor, J. A. (2001). Stimuli inevitably generated by behavior that avoids electric shock are inherently reinforcing. *Journal of Experimental Analysis of Behavior*, *75*, 311-333.

Eriksen, J., Jensen, M. K., Sjogren, P., Ekholm, O., & Rasmussen, N. K. (2003). Epidemiology of chronic non-malignant pain in Denmark. *Pain*, *106*, 221-228.

Fuhrer, J. C. (2000). Habit formation in consumption and its implications for monetary-policy models. *American Economic Review*, *90*, 367-390.

Laming, D. R. J. (1997). *The measurement of sensation*. London: Oxford University Press.

Macfarlane, G. J., Jones, G. T., & McBeth, J. (2005). Epidemiology of pain. In S. B. McMahon and M. Koltzenburg (Eds.), *Wall and Melzack's textbook of pain* (pp. 1199-1214). 5 ed. Philadelphia: Elsevier.

McMahon, S. B., & Koltzenburg, M. (eds.) (2005). *Wall and Melzack's textbook of pain* (5 ed). Philadelphia: Elsevier.

Morris, R. G. M. (1975). Preconditioning of reinforcing properties to an exteroceptive feedback stimulus. *Learning and Motivation, 6*, 289-298.

NFO World Group (2007). Pain in Europe. Available from: URL: http://www.paineurope.com/.

Nieuwenhuis, S., Heslenfeld, D. J., von Geusau, N. J., Mars, R. B., Holroyd, C. B., & Yeung, N. (2005). Activity in human reward-sensitive brain areas is strongly context dependent. *Neuroimage*, *25*, 1302-1309.

Osborn, D.R. (1988). Seasonality and habit persistence in a life cycle model of consumption. *Journal of Applied Econometrics*, *3*, 255-266.

Parducci, A. (1965). Category judgment: A range-frequency theory. *Psychological Review*, *72*, 407-418.

Parducci, A. (1995). *Happiness, pleasure and judgment: The contextual theory and its applications*. Mahwah, NJ: Lawrence Erlbaum.

Rescorla, R. A. (1969). Establishment of a positive reinforcer through contrast with shock. *Journal of Comparative and Physiological Psychology*, *67*, 260-263.

Seymour, B., O'Doherty, J. P., Dayan, P., Koltzenburg, M., Jones, A. K., Dolan, R. J., Friston, K. J., & Frackowiak, R. S. (2004). Temporal difference models describe higher-order learning in humans. *Nature*, *429*, 664-667.

Seymour, B., O'Doherty, J. P., Koltzenburg, M., Wiech, K., Frackowiak, R., Friston, K., & Dolan, R. (2005). Opponent appetitive-aversive neural processes underlie predictive learning of pain relief. *Nature Neuroscience*, *8*, 1234-1240.

Shafir, E., & LeBoeuf, R. A. (2002). Rationality. *Annual Review of Psychology*, *53*, 491-517.

Singer, T., Seymour, B., O'Doherty, J., Kaube, H., Dolan, R., & Frith, C. (2004). Empathy for pain involves the affective but not sensory components of pain. *Science*, *303*, 1157-1162.

Slovic, P. (1995). The construction of preferences. *American Psychologist*, *50*, 364-371.

Smith, A. (1759). *The theory of moral sentiments*. Oxford: Clarendon Press.

Stewart, N., Brown, G. D. A., & Chater, N. (2005). Absolute identification by relative judgment. *Psychological Review*, *112*, 881-911.

Tobler, P. N., Fiorillo, C. D., Schultz, W. (2005). Adaptive coding of reward value by dopamine neurons. *Science*, *307*, 1642–1645.

Tremblay L, & Schultz, W. (1999). Relative reward preference in primate orbitofrontal cortex. *Nature*, *398*, 704-708.

Veblen, T. B. (1899). *The theory of the leisure class: An economic study of institutions*. Modern Library, New York.

Weisman, R. G., & Litner, J. S. (1969). Positive conditioned reinforcement of sidman avoidance behavior in rats. *Journal of Comparative and Physiological Psychology*, *68*, 597-603.

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Figure Captions

Figure 1. Experimental task. (*a*) Buying relief in a computerised second price auction. In each trial, participants first saw the financial endowment for that trial, followed by a single exemplar painful electric shock, of an either low, medium or high intensity. Participants were not informed, nor did they identify, that the pain consisted only 3 discrete levels. They then selected the maximum price they we prepared to pay to avoid 15 further shocks. The maximum price they could offer was their full endowment, which was given on a strictly trial by trial basis (such that there is no sense that endowments could be 'saved' or carried over to pay for later pain relief). The market price was set randomly between zero and the full endowment amount, and if this was lower than the participant's price offer, the 15 painful stimuli were omitted at the cost of the market price (and *not* the participant's offer). (*b*) Grouping of trials (pain levels) into Low-Medium, High-Medium and Low-High blocks. We repeated each block twice so there were 6 blocks and 60 trials in total. The order of pain levels within each group was randomised, as was the overall order of the blocks.

Figure 2. Mean price offers depending on endowment and context pairing. The figure shows the mean prices (error bars = +/- 1 s.e.m.) for the different levels of pain as a function of context provided by the block. (*a*) refers to the 40p endowment group of participants, and (*b*) presents the 80p endowment group of participants. The medium pain level (red squares) provokes markedly different mean price offers according to whether it occurs in a block with low, or high level pain, in both *a* and *b*. In (*c*), we plot this difference as a function of round within each block, which shows that the discrepancy provided by the context increases through the block, consistent with the notion that context for each block takes time to become established.

Figure 3. Demand curves for pain relief, which are derived only from the trials following experienced (consumed) long pain. Demand curves reflect the quantity of pain relief that can be expected to be sold at different prices. In other words, the demand is indicated by the number of price offers within a certain price range (below a certain level), which shows how many potential sells would have occurred if the market price was within this price range. These are shown separately for each pain level (*a*-*c*) and endowment amount.

Figure 1

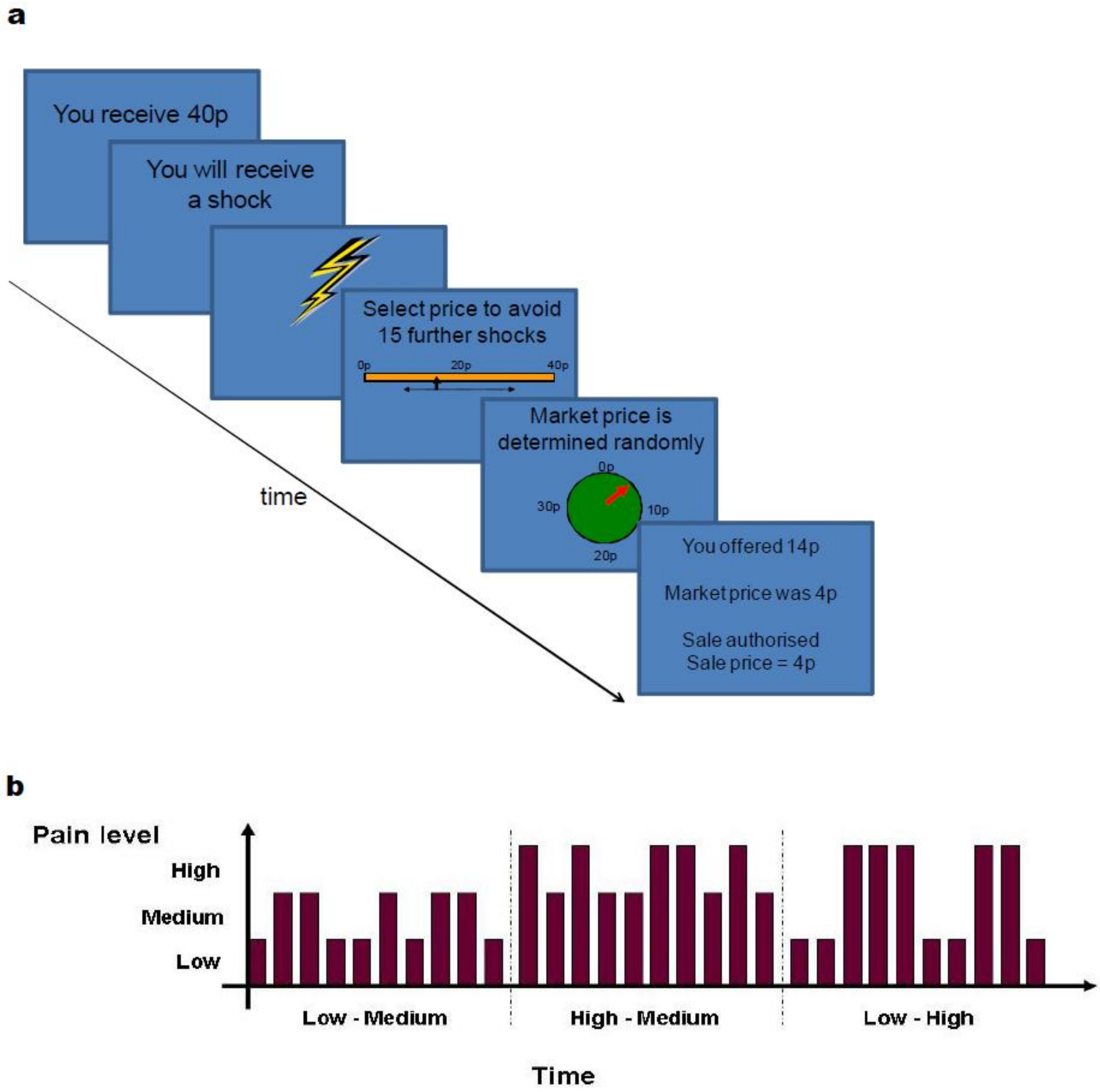

a
You receive 40p
You will receive a shock
Select price to avoid 15 further shocks
0p
20p
40p
Market price is determined randomly
0p
10p
20p
30p
You offered 14p
Market price was 4p
Sale authorised
Sale price = 4p
time
b
Pain level
High
Medium
Low
Low - Medium
High - Medium
Low - High
Time

Figure 2

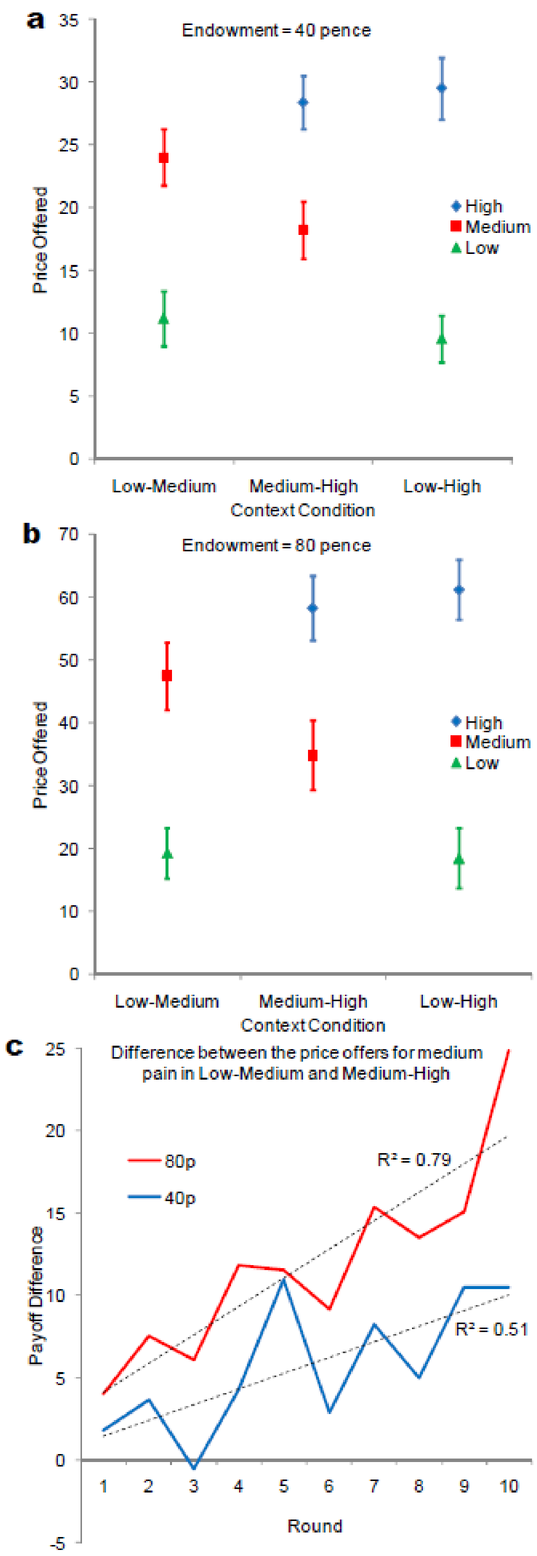
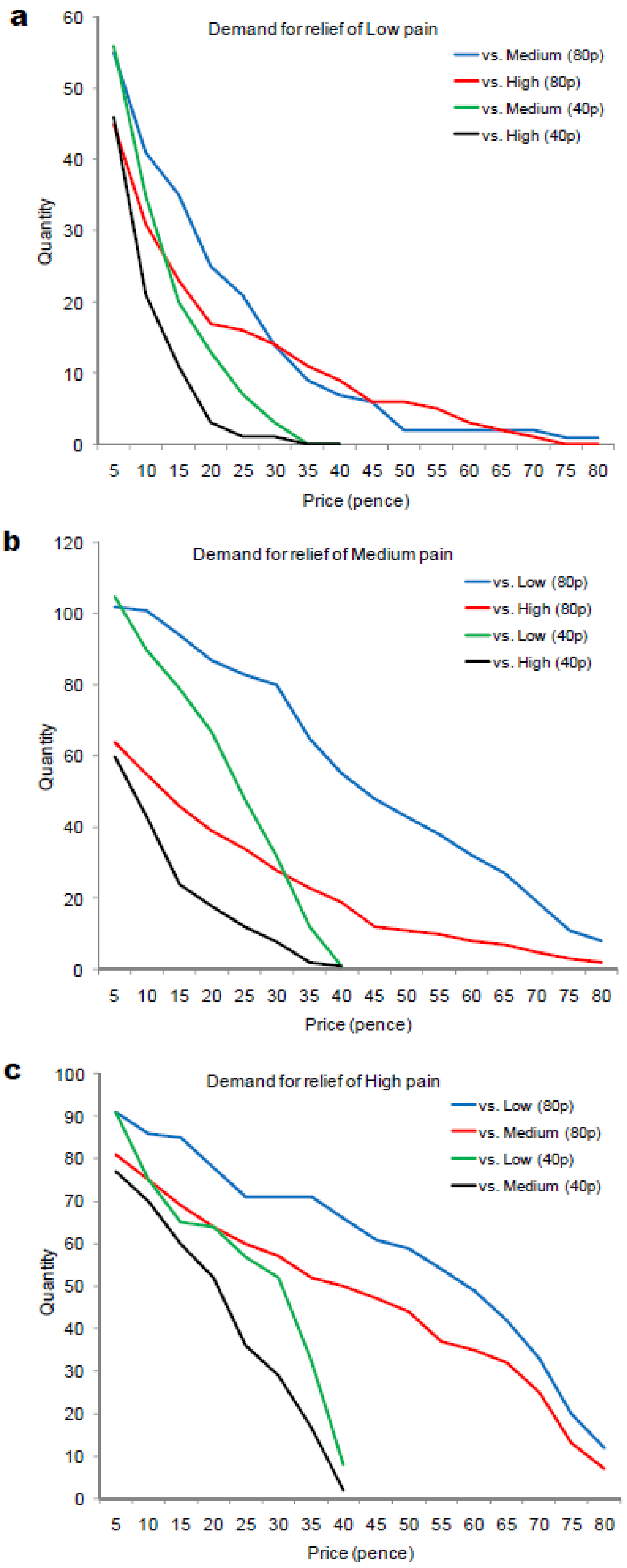

a
Endowment = 40 pence
Price Offered
35
30
25
20
15
10
5
0
High
Medium
Low
Low-Medium
Medium-High
Low-High
Context Condition
b
Endowment = 80 pence
Price Offered
70
60
50
40
30
20
10
0
High
Medium
Low
Low-Medium
Medium-High
Low-High
Context Condition
c
Difference between the price offers for medium pain in Low-Medium and Medium-High
Payoff Difference
25
20
15
10
5
0
-5
80p
40p
R² = 0.79
R² = 0.51
1
2
3
4
5
6
7
8
9
10
Round

Figure 3


a
Demand for relief of Low pain
vs. Medium (80p)
vs. High (80p)
vs. Medium (40p)
vs. High (40p)
Quantity
Price (pence)
b
Demand for relief of Medium pain
vs. Low (80p)
vs. High (80p)
vs. Low (40p)
vs. High (40p)
Quantity
Price (pence)
c
Demand for relief of High pain
vs. Low (80p)
vs. Medium (80p)
vs. Low (40p)
vs. Medium (40p)
Quantity
Price (pence)