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How does the perception of pain determine the selection between different treatments? Experimental evidence for convex utility functions over pain duration and concave utility functions over pain intensity

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ABSTRACT

We test the QALY concept to evaluate the utility of therapies. The QALY is the sum of the duration of each health state a patient faces weighted by the utility the patient obtains from this state. The QALY implies linear utility functions over duration. Corresponding analyses for health-related decisions are problematic as inducing health levels is difficult. In this study, we evaluate both utilities over pain duration for a fixed pain level and over pain intensity for a fixed duration, with real health consequences, using the cold pressor test. We find that, for human decision-makers, utility over pain duration does not increase linearly over time when making health-related decisions. This suggests that the QALY might not capture preferences as intended.

1. Introduction

One key issue of decision-making in the context of health regards making allocations: Health-related resources, be they the working hours of medical practitioners, capacities of medical equipment, or research capacities for new drugs, are scarce. Hence, to guarantee the best level of health supply that can be afforded, the treatment of patients must be prioritized. While the cost of each treatment is objectively measurable, the benefit is not. Think of cancer treatment: It is often possible to choose between chemotherapy and surgery. Disregarding the price of both treatments, which is better for the patient?

One approach to selecting the most beneficial treatment from among all available treatments is the calculation of the quality adjusted life years of a patient (QALY; see Weinstein et al., 2009). The government of the UK, for instance, uses QALY to measure the benefits of different treatments and to allocate resources (see e.g., Mason et al., 2009). Aside from the UK, the US, Australia, Canada, and several other countries have discussed the introduction of QALY for cost benefit analyses (Neumann and Greenberg, 2009), further strengthening the importance of concepts for evaluating treatment benefits. Since

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governments often determine the supply of treatments according to criteria like QALY, the supply side depends on corresponding measures: Only if the QALY improvement of a treatment is high relative to its cost increments the costs will be paid by the health system.

To calculate QALY, the different health states x of a patient are identified, and each health state is assigned a utility value $u(x)$. Typically, $u(x) = 1$ represents the state of perfect health and $u(x) = 0$ represents immediate death. All health states are then weighted with the duration t_x for which a patient faces them. Hence, formally, the QALY equals $\sum_{x \in X} u(x) \cdot t_x$ with X being the set of all health states the patient experiences. Notice the similarity of the QALY and the utility function from expected utility theory ($\sum_{x \in X} u(x) \cdot p_x$, see von Neumann and Morgenstern, 1944). This equation implies linear utility functions over time (see Pliskin et al., 1980). According to the QALY, patients do not distinguish between facing a certain health state earlier or later in their lives, and they do not take their remaining lifetime into account when choosing between treatments.

From a behavioral perspective, two main arguments counter linear utility functions over durations: (1) Economists would expect later health states to be discounted (see e.g., Attema et al., 2012); and (2) psychologists have shown that the duration of a health state is less important than its utility. Patients often focus on the last and most intense experience they face neglecting its duration (Fredrickson and Kahneman, 1993), or they simply add the utility of the duration to the utility of the health state itself (Schreiber and Kahneman, 2000). Whether duration is neglected or added to the utility of the health state depends on the attention a patient invests as well as the specific study design (Ariely and Loewenstein, 2000; Ariely et al., 2000).

The behavioral arguments against linear utility functions over durations are a result of the human processing of temporal information (see Ariely, 1998; Ariely and Loewenstein, 2000; Diener et al., 2001; Fredrickson and Kahneman, 1993; Varey and Kahneman, 1992): Patients simply tend to forget or push away negative experiences the longer they are removed from them. In consequence, recent or even the last negative experience influences behavior. In this sense, both subjects facing pain due to hand immersion into cold water (Kahneman et al., 1993) and subjects facing colonoscopy (Redelmeier and Kahneman, 1996; Redelmeier et al., 2003) favor longer pain durations—if a short comfortable experience is added to the end. Consequently, evaluating the quality of different health states using a within-subject experiment or questionnaire can yield unreliable results.

As a result, one question arises: If only one health state can be evaluated to get reliable results, is varying evaluation over time important in any way? The answer is clearly, "yes." In addition to reducing the weight of future health states, non-linear evaluation of time can impact the value of the sum of health states. Each health state is subject to temporal aspects, that is, it consists of the well-being on the first, second, third day, etc. of the health state. A varying evaluation of different days would imply that time is not a linear parameter. Hence, for trustworthy measurement, utility functions must be derived over durations. Interviews with cancer patients during therapy elicit concave utility functions over their remaining time of life (McNeil et al., 1978, 1981). The concavity of durations is imminent not only in patients suffering from cancer but also in healthy people (Oliver and Cookson, 2010; Rosen et al., 2003; Stiggelbout et al., 1994; Verhoef et al., 1994). Linear utility functions over time lack experimental confirmation. In one exception (Miyamoto and Eraker, 1985), linearity is found in the aggregate over all subjects, but seldom in individual subjects.

In sum, experimental work with a focus on human information processing indicates that preferences of durations should be evaluated with a focus on one health state only to suppress anomalies introduced by forgotten earlier experiences. Interviews (i.e., analyses without real consequences) show that utility functions over durations are concave. However, the utility function elicited from stated preferences varies between hypothetical and real choice situations (see e.g., Holt and Laury, 2002, 2005).

Hence, we compare utility functions captured in interviews with utility functions derived from a central component of the QALY, pain.[1] We aim to specify the curvature of two utility functions: over pain intensity (reflecting a reduction of quality of life) for a constant duration and over pain duration (reflecting life time spent in a certain health state) for a constant pain. We induce pain using the cold pressor test (Hines and Brown, 1936). That is, we ask subjects to immerse one hand in painfully cold water. The cold pressor test generates a deep, tonic, thermal pain (Lorenz, 2002) and is commonly applied in pain research (Hines and Brown, 1936; Kahneman et al., 1993; Lovallo, 1975; Streff et al., 2010), especially for studies simulating chronic pain (Mitchell et al., 2004).

For the hand immersion into cold water, we find subjects to have convex utility functions over pain duration and concave utility functions over pain intensity. The results are surprising, both from an economic and a medical perspective. Economists might have expected the utility function over health states to be concave, as in expected utility theory. However, another approach according to prospect theory (Kahneman and Tversky, 1979) regards pain as a loss compared to the state of perfect health the subjects face in the beginning of the experiment. Following the approach based on prospect theory, the curvature of the utility function over pain intensity should be convex. This result calls for intensifying experimental work on the way the benefits of treatments are perceived by the subjects. At least for pain induced by cold water, modeling suggested by the QALY concept might not be appropriate.

[1] We are aware of the fact that quality of life consists of more than pain. In the discussion, we argue why we nevertheless believe that pain is the central aspect of quality of life analyses.

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