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Nicotine reduction as an increase in the unit price of cigarettes: A behavioral economics approach☆,☆☆

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ABSTRACT

Urgent action is needed to reduce the harm caused by smoking. Product standards that reduce the addictiveness of cigarettes are now possible both in the U.S. and in countries party to the Framework Convention on Tobacco Control. Specifically, standards that required substantially reduced nicotine content in cigarettes could enable cessation in smokers and prevent future smoking among current non-smokers. Behavioral economics uses principles from the field of microeconomics to characterize how consumption of a reinforcer changes as a function of the unit price of that reinforcer (unit price = cost/reinforcer magnitude). A nicotine reduction policy might be considered an increase in the unit price of nicotine because smokers are paying more per unit of nicotine. This perspective allows principles from behavioral economics to be applied to nicotine reduction research questions, including how nicotine consumption, smoking behavior, use of other tobacco products, and use of other drugs of abuse are likely to be affected. This paper reviews the utility of this approach and evaluates the notion that a reduction in nicotine content is equivalent to a reduction in the reinforcement value of smoking—an assumption made by the unit price approach.

Introduction

The Family Smoking Prevention and Tobacco Control Act gives the FDA the authority to regulate cigarettes (US Congress, 2009). Included in the act is the authority to reduce the content of nicotine to any non-zero level, a strategy that has been suggested for reducing the prevalence of smoking (Benowitz and Henningfield, 1994, 2013; US Department of Health and Human Services, 2014). Similar standards could be set by countries party to the Framework Convention on Tobacco Control; Article 9 allows for guidelines on the regulation of the content and emissions of tobacco products. Recent studies support nicotine reduction as a promising approach by showing that substantial reductions in nicotine content can result in reduced toxicant exposure and, in some cases, a reduction in smoking behavior and dependence (Benowitz et al., 2007, 2012; Donny et al., 2007; Hatsukami et al., 2010a,b). Notably, required reductions in the *nicotine content* in cigarettes would differ from existing reduced yield cigarettes which yield less nicotine when smoked by a machine, but less so when smoked by humans (Hoffmann and Hoffmann, 2001).

Behavioral economics: a unique framework for nicotine reduction

Behavioral economics borrows principles from the field of microeconomics to describe how consumption of a reinforcer changes as the unit price of that reinforcer is manipulated (unit price = cost/reinforcer magnitude) (See Hursh and Roma, 2013 for a recent review and tutorial of the approach). A behavioral economics framework asserts that consumption of a reinforcer is related to the unit price of that reinforcer and the unit price of concurrently available reinforcers. Manipulations in unit price often take place through increases in cost (i.e., the numerator) such as increases in monetary value, effort, or time required obtaining the reinforcer (Hursh and Roma, 2013). An example of this approach is taxation, which has been reliably shown to drive down consumption (Chaloupka and Warner, 1999). Importantly, a decrease in the magnitude of the reinforcer (i.e., the denominator) should be functionally equivalent to an increase in cost (Bickel et al., 1990) and may represent an underutilized approach to tobacco control. The relationship between cost and reinforcer magnitude is rather intuitive on

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the surface—if the price of a pack of cigarettes is doubled, the change in cigarette consumption should be the same as if the number of cigarettes in a pack was cut in half, because the price per cigarette (i.e., unit price) has been changed in the same way.

Decades of research suggest that the primary reason people smoke is to obtain nicotine (Stolerman and Jarvis, 1995; US Department of Health and Human Services, 1988). Hence, a reduction in nicotine content may be thought of as an increase in the unit price of nicotine. This perspective allows for the application of behavioral economics approaches to be applied to research questions related to potential product standards for nicotine (Donny et al., 2012). The purpose of the present paper is to describe how a behavioral economics framework might be used to advance research related to nicotine regulation, and discuss the implications of such a framework.

How will nicotine reduction affect nicotine consumption and smoking behavior?

Behavioral economics uses demand curves to characterize changes in the consumption of a reinforcer as a function of unit price (Hursh and Silberberg, 2008). An example of a demand curve and a curve showing corresponding changes in behavior can be seen in Fig. 1. Assuming people smoke to obtain nicotine, a demand curve can be generated by using nicotine content as reinforcer magnitude to calculate unit price. However, changes in nicotine content may not translate easily into changes in nicotine intake (Fig. 1), as intake will be influenced by changes in smoking behavior (e.g., cigarettes per day, puff volume). In a hypothetical nicotine reduction policy, nicotine content is reduced but other, potentially harmful, cigarette components, such as tar, remain unchanged. Thus, any increase in smoking behavior (i.e., any compensation) will likely result in a negative health impact. Nicotine intake can be measured through the use of biomarkers of nicotine exposure (e.g., cotinine, total nicotine equivalents). This approach should account for all the ways in which nicotine intake can change as a function of changes in smoking behavior. The behavioral output (Fig. 1) required to achieve a given level of nicotine intake is best viewed as a composite measure of smoking behavior and should be closely related to total smoke exposure.

An exponential equation, shown in Fig. 1, can be used to describe demand curves (Hursh and Silberberg, 2008). Demand curves are typically downward sloping in that consumption (*Q*) decreases as the unit price of the reinforcer (*C*) is increased, suggesting that nicotine intake is likely to decrease as nicotine content is decreased. Across a range of low unit prices, decreases in nicotine intake are proportionally *less than* the increase in unit price and demand is referred to as inelastic. Decreases in nicotine intake as unit price is increased are less than might be predicted because smoking behavior, and consequently smoke exposure, increases (i.e., compensation). Across a range of higher unit prices, decreases in nicotine intake are proportionally *greater than* the increase in unit price and demand is referred to as elastic. In this case, decreases in nicotine intake are greater than might be predicted because smoking behavior decreases as unit price increases. The estimated unit price at which demand would switch between inelastic and elastic is termed P_{max}, and at this unit price the predicted maximum amount of behavioral output (i.e., compensation), termed O_{max}, would be observed. Thus, when smoking behavior is plotted as a function of descending nicotine content, the function is likely to have an ascending and a descending limb, corresponding to the inelastic and elastic portions of a demand curve. For any level of smoking behavior (and smoke exposure) on the inelastic portion of the curve, there is a price that will produce equivalent smoking behavior on the elastic portion of the curve. Unit prices between these two prices result in compensation and unit prices outside of this range result in decreased exposure. Given one of these two unit prices and a complete demand curve, the corresponding unit price could be easily calculated. The two free parameters in Eq. (1), Q_0 and α, describe predicted nicotine intake when the reinforcer is free (graphically the *y*-intercept), and sensitivity to increases in unit price (graphically the rate of change in slope), respectively (Hursh and Silberberg, 2008). Data suggest that the typical relationship between unit price, intake, and behavioral output, is indeed likely to extend to changes in nicotine content (Bickel et al., 1991). DeGrandpre et al. (1992) reanalyzed 17 data sets from studies where nicotine yield was manipulated (e.g., through brand switching, shortened cigarettes), and found that nicotine intake adhered to typical demand curves.

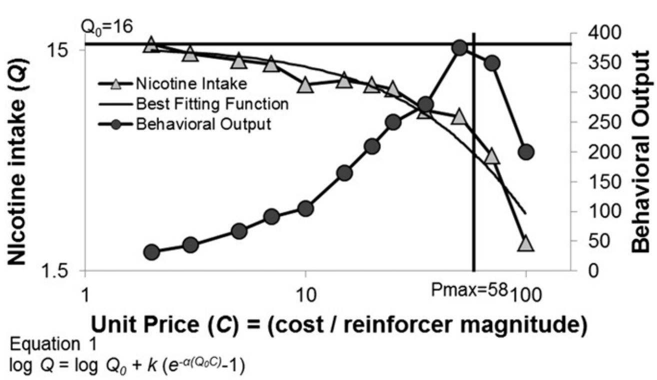

Fig. 1. Demand curve. Example of demand curve plotting consumption as a function of unit price (triangles) and corresponding changes in behavior (circles). The demand curve plots nicotine consumption as a function of increases in unit price. Best fitting function for the demand curve using Eq. (1) is plotted using solid line. In Eq. (1), *Q* and *C* are consumption and unit price, respectively; *k* is a scaling parameter specifying the range of the dependent variable. Q_0 is a free parameter estimating consumption if the reinforcer were free (graphically the *y*-intercept), and α is a free parameter describing sensitivity to increases in unit price (graphically rate of change in the slope). P_{max} is the unit price at which demand switches from inelastic to elastic (plotted here as the P_{max} estimated from Eq. (1)), and at this price, the maximum amount of behavioral output is observed.

Demand curves provide a more complete characterization of the relationship between changes in nicotine content and nicotine intake than traditional measures. Previous nicotine research has used a compensation index (CI) (Benowitz et al., 2005, 2012; Grebenstein et al., 2013; Harris et al., 2011; Scherer, 1999; Stephen et al., 1989). This approach has been frequently used to study differences in machine-measured nicotine yields between regular and light or ultralight cigarettes; however, the same concept can be applied to manipulations of nicotine content, when other features of product design are assumed to be constant:

$$\mathrm{CI} = 1 - [\log(\mathrm{marker}_2) - \log(\mathrm{marker}_1)]/[\log(\mathrm{content}_2) - \log(\mathrm{content}_1)] \quad (2)$$

in which marker_1 and marker_2 refer to biomarkers for nicotine intake before and after nicotine reduction, respectively, and $\mathrm{content}_1$ and $\mathrm{content}_2$ refer to nicotine contents before and after nicotine reduction, respectively. The CI measure is related to demand curves because for any two points on a demand curve, the CI will correspond to the slope of a line connecting those two points on a demand curve. An example is shown in Fig. 2. The CI between unit price A and unit price D would be the same as the CI between unit price B and unit price C, as the proportional change in intake as a function of change in price is the same. However, to say that behavior has been changed in the same way between each of the two sets of prices is misleading. A reduction in nicotine from unit price A to unit price D has shifted demand to the elastic portion of the demand curve, and further reductions in nicotine content will decrease smoking behavior. A reduction in nicotine from unit price B to unit price C has failed to shift demand to the elastic portion of the demand curve. Further reductions in nicotine content will result in increased smoking behavior. In fact, unit price C is nearing Pmax, the unit price that will result in the highest level of smoking behavior. Hence, although the CI is useful for summarizing compensatory change between any two points, it cannot capture the nature of the relationship or be used to predict what additional changes in content might do to behavior.