Prospecting the use of reaction times, response force and partial response force to estimate consumers' willingness-to-pay.

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Abstract

The present study employed an explicit reaction time task but measured several underlying cognitive processes in an attempt to provide implicit estimates of consumers' willingness-to-pay (WTP). Participants were asked to evaluate product-price combinations as cheap or expensive. The prices of the products ranged from very cheap to very expensive. Crucially, participants had to complete the task under time pressure while the dependent variables of interest could not be influenced deliberately. This is because we explored whether the magnitude of the price stimulus interfered with the reaction times (RTs), response force (RF) and partial responses (PRs). The results of our study demonstrated that both RTs and RF are influenced by the magnitude of the price and it is postulated that these dependent measures indeed have the potential to investigate consumers' WTP. Future studies need to further investigate the possibilities of these implicit variables and validate eventual estimates.

Introduction

The economic advantages of value-based pricing strategies in generating revenue compared with other pricing strategies are immense (Hinterhuber & Bertini, 2011; Ingenbleek, 2007; Liozu & Hinterhuber, 2015). This pricing strategy starts from the premise that the price of a product should align with what consumers are actually willing to pay (Armstrong, G., Adam, S., Denize, S., & Kotler, 2014). More conventional pricing strategies often focus on production costs or competition to guide pricing decisions. The latter pricing strategies are more convenient to implement because they rely on objective numbers that are easy to measure (i.e. costs related to the production or prices of competing products). Outlining value-based pricing strategies is more challenging because pricing decisions need to incorporate what consumers are actually willing to pay, and reliably estimating this price point has proven to be difficult (Hinterhuber, 2008). Willingness-to-pay (WTP) is usually defined as the monetary expression of the perceived value of products or services (Balderjahn, 2003; Gall-ely, 2009). Consumers' comparisons between the selling price and the internal reference price (IRP) are believed to be a crucial factor in the formation of WTP (Bell, Lattin, Bell, & Lattin, 2000; Martins & Monroe, 1994; Thaler, 1985). Monroe (1973) first introduced IRPs as dynamic price standards used by consumers as anchors to evaluate prices. Additional research (Kalyanaram & Winer, 1995; Winer, 1986) stipulated that prices above the IRP are likely to be perceived as 'expensive', while prices below this point are mostly perceived as 'cheap'. This was further verified by multiple studies that demonstrated that IRPs can have a strong impact on purchase decisions (Kim, Natter, & Spann, 2008; Lowe & Alpert, 2010; Mayhew & Winer, 1992; Rajendran & Tellis, 1994) and consequentially on

consumers' WTP (Herrmann, Xia, Monroe, & Huber, 2007; Mazumdar, Raj, & Sinha, 2005; Ranyard, Charlton, & Williamson, 2001).

Numerous approaches to measure consumers' WTP have been put forward over the past decades (Breidert, Hahsler, & Reutterer, 2006; Lipovetsky, Magnan, & Zanetti Polzi, 2011; Miller, Hofstetter, Krohmer, & Zhang, 2002). Most of these methods are based on stated and therefore explicit consumer responses. For example, the price-sensitivity meter (Kloss & Kunter, 2016; van Westendorp, 1976) is a procedure where consumers are asked to state the price that is (too) cheap or (too) expensive for a product. These self-reports often fall short in providing valid WTP estimates. This is because consumers often fail to retrieve accurate information about their WTP (Braun, 1999; Dimofte, 2010; Spence & Townsend, 2007) or might be reluctant to share this information (Oskamp & Schultz, 2005). Furthermore, these methods inherently assume that consumers are rational, well-informed and therefore optimal decision makers (Cheng & Monroe, 2013a; Simonson, Carmon, Dhar, Drolet, & Nowlis, 2001).

Research using this cognitive framework mostly neglected the contribution of heuristics, emotions, feelings, perceptions, and automatic processing in the construction of price evaluations (Adaval, 2013; Coulter, 2013; Rao, 2013). Behavioral price research offers a novel view on this traditional framework by shifting the focus from deliberate and rational, to automatic and emotional processes (Cheng & Monroe, 2013b; Estelami & Maxwell, 2003; Homburg, Hoyer, & Koschate, 2005; Lehrer, 2009; Slovic, Finucane, Peters, & Macgregor, 2004, 2007). Recent pricing studies have shown that exposure to price information elicits physiological, psychological and emotional reactions (Adaval, 2013; Coulter, 2013). Price evaluations are likely to be construed via automatic interpretations of these non-deliberate reactions (Cheng & Monroe, 2013a; Dezwaef, Cracco, Demanet, Desmet, & Brass, 2019) and

Peine, Heitmann, & Herrmann (2009) demonstrated that effortful cognitive processing of price information automatically triggers implicit emotional responses towards prices which affect purchase decisions. Hence, price evaluations seem to be the result of both non-deliberate, cognitive and affective processing. In the current study it was investigated whether these non-deliberate processes can be indexed and if they contain valuable information about consumers' WTP. Participants were asked to evaluate price stimuli as 'cheap' or 'expensive' while information about three non-deliberate processes was collected: reaction times (RTs), response force (RF) and partial responses (PRs). We defined these measures as follows. RTs index the time needed to make price evaluations. RF is used to refer to the force that was applied to press the button when indicating the decision. As to our best knowledge no studies investigated PRs, albeit in the context of error processing so-called partial errors are used as a measure of subthreshold motor activity. Partial errors have been shown to be poorly detected by participants (Rochet et al., 2014). Moreover, previous research (Donner, Siegel, Fries, & Engel, 2009; Wojnowicz, Ferguson, Dale, & Spivey, 2009) defined partial errors as undeliberate response tendencies preceding the actual response.

In the current study, PRs were defined as the registered RF associated with the response button opposing the eventual price evaluation (see below for a more detailed definition). Note that all variables of interest can be considered as 'implicit variables' because the measured data points are assumed to be the result of non-deliberate processes. Therefore, it was assumed that all investigated variables (RTs, RF and PRs) could potentially provide implicit information about consumers' WTP, and consequentially circumvent biases related to stated-consumer responses. Importantly, price evaluations (i.e., 'cheap' vs. 'expensive' evaluations) were operationalized as tangible motor conflicts (i.e., press the left button if you consider the price 'cheap' vs. press the right button if you consider the price 'expensive') by continuously

sampling the pressure applied to the response buttons throughout the price evaluation process. This allowed to capture manifestations of competing response tendencies on the motor level. Furthermore, price stimuli were manipulated to be perceived as ambiguous or unambiguous in the degree of expensiveness. We now briefly discuss each variable and outline how the measure can be related to consumers' WTP. As defined above, RTs index the time needed to evaluate prices as 'cheap' or expensive'. The time needed to formulate an evaluation can be interpreted as the strength of the association between the stimulus (i.e. price) and the evaluation (Fazio, 2007; Oskamp & Schultz, 2005). While readily available evaluations result in fast decisions (i.e., low RTs), hidden or conflicting preferences are less easily activated and result in longer decision times (i.e., high RTs). This logic can be extrapolated to the current study. When prices are perceived as clearly 'cheap' or 'expensive', decisions are assumed to be fast (i.e., low RTs). Conversely, if prices are perceived neither 'cheap' or 'expensive', then decisions are expected to be more difficult and therefore slower (i.e., higher RTs). However, during the preparation of a response multiple potential action plans (e.g., evaluate the price as 'cheap' or 'expensive') compete to be selected (Gallivan & Chapman, 2014; Gold & Shadlen, 2007; Lagzi & Rotter, 2015; Murakami & Mainen, 2015).

Since RTs solely provide information about the final output of a response, they can only be used as an indirect measure of response competition. Instead, measuring the force applied to the response buttons (i.e. RF and PRs) does allow to investigate dynamics of motor behavior and provide insights into unfolding decision processes (Freeman & Ambady, 2009; Freeman, Dale, & Farmer, 2011; Rosenbaum, 2005; Song & Nakayama, 2008; Spivey & Dale, 2006). That is, ongoing competition between alternative responses (e.g., 'cheap' or 'expensive' evaluation) can be measured in movement dynamics. Interestingly, the RF used to give the eventual response (e.g., pressing button X to evaluate a price as 'cheap') is directly

related to the degree of response conflict present during the response selection (Abrams & Balota, 1991; Kantowitz, 1973) and PRs appear to be under minimal conscious control (Rochet et al., 2014). Hence, indexing the movement dynamics during decision-making tasks might shed light on the confidence with which a response was given. This yields information that would conventionally remain undetected with standard discrete RT measures (Freeman & Ambady, 2011; Song & Nakayama, 2006, 2008, 2009). Within the used framework, it would be expected that prices that are perceived as either clearly 'cheap' or 'expensive' are evaluated with more confidence. This would result in higher RF and less PR activity. In contrast, price stimuli that are ambiguous might result in more doubtful responses, resulting in lower RF and more PR activity.

Method

Participants

A total of 36 participants with normal or corrected-to-normal vision (17 females; MAge = 23.6 years, SDAge = 3.97, ranging from 18 to 39 years old) were recruited via the online recruitment platform of the University of Ghent. The study was conducted in accordance with the ethical standards of the 1964 Declaration of Helsinki and approved by the Institutional Review Board from the Faculty of Psychology and Educational Science of Ghent University. Prior to the experiment, participants gave their written informed consent and were informed that participation was voluntary, and that all data would be processed and stored anonymously.

Procedure

Participants were seated in front of a computer and were briefly introduced to the task. Then, instructions on the screen explained that they had to evaluate a sequence of product-price combinations as fast as possible as 'cheap' or 'expensive'. In total, eight products with seven different prices were presented exactly six times in a random order divided across six blocks. Self-paced breaks were included after each block. Consequently, each participant completed 336 trials. Each trial started with a fixation cross that was presented on the screen for 500 milliseconds. After the fixation cross, the product was presented 1500 milliseconds. Then the product was removed from the screen and the price stimulus was presented for a maximum of 1000 milliseconds or until a response was given. When participants failed to respond before the response deadline (i.e., 1000 ms), a warning message with "Te traag!" (i.e., "Too slow" in Dutch) appeared on the screen for 500ms. A response deadline of 1000 milliseconds was retained to minimize the influence of answering strategies (Ackermann & Mathieu, 2015) and to counteract participants' awareness of the artificiality of the testing situation, which in turn promotes truthful responses (Harrison & Rutström, 2008). The inter-trial interval was set to 1500 milliseconds. Throughout the complete trial sequence response force was indexed at a sampling rate of 128 Hertz.

Materials

Eight products (iced tea, cola, cream cheese, mints, orange juice, potato chips, ham and candy) of well-known brands were selected for the study. Based on the selling price of the products at the moment of the study (i.e., retail price) additional price stimuli were created. The retail price was manipulated in three steps in order to create prices of which we assumed that they would be perceived as either 'cheap', 'expensive' (i.e., unambiguous) or

‘normal’ (i.e., ambiguous). To create the different price conditions, we either added or subtracted 10%, 40% or 70% to the retail price. The highest price used was €6.36 and the lowest price used was €0.37. In total, this resulted in 56 product-price combinations.

Stimuli were presented on a computer display positioned approximately 10 cm behind a self-engineered response box (National Instruments Labview RunTime Engine, 2015; Arduino, 2018), with the response box (10,5 cm x 19,5 cm x 3,5 cm; width x length x height) in front view within comfortable reach. Participants responded by pushing the buttons (left or right, separated by 10 cm) of the response box equipped with pressure sensors using the index fingers of both hands. The force applied to both buttons was continuously registered throughout the trials and RTs were registered with millisecond accuracy. Stimulus presentation and response registration were controlled by Tscope5, which is a C/C++ experiment programming library for cognitive scientists (Stevens, Lammertyn, Verbruggen, & Vandierendonck, 2006).

Data pre-processing

Both pre-processing of the raw data and statistical analyses were performed in RStudio (R Core Team, 2018). Prior to further preprocessing, trials with reaction times below 200 milliseconds (0.02%) were removed, as well as trials exceeding the response deadline (i.e., >1000ms; 5.06%). Next, one participant was excluded because the mean number of ‘too late’ responses deviated more than 2 standard deviations from the sample mean. Finally, trials were excluded when the RF was smaller or larger than two standard deviations of the average response force of the participant (3.75%).

Subsequently, baseline RF values were calculated on a trial-by-trial basis for both response buttons. For each trial (Figure 1, step 1 and 2), two baseline values were computed

by averaging the force applied to each button (i.e., baseline 'cheap' and baseline 'expensive') in a post-price stimulus interval ([100ms – 260ms]). Then, the peak force of each button in each trial was selected with a customized algorithm which identified the maximum force value of both buttons within each trial. The peak forces were then baseline corrected by subtracting the force of the baselines from the peak forces. The baseline values were calculated to average out random fluctuations in the response force registration and to account for initial differences in the applied force between the buttons. Only the baseline corrected peak force values linked to the price evaluations of the trial were included for RF analysis.

Figure 1. Overview of the procedure used to detect partial responses.

The force activity registered on the button opposite to the overt response was categorized as a partial response (PR) based on the procedure outlined in Figure 1. First, the baselines for both responses on each trial were calculated as the average force within the predetermined post-price window (step 1 and 2). Then, a threshold value was determined for each participant individually as 10% of the average difference between the overt peak force and its corresponding baseline over all trials (step 3). Fourth, the difference between the partial peak force and its baseline was computed for each trial (step 4). Finally, a detection interval of 336 ms starting 24 ms before the peak of the overt RF was established such that PRs always preceded and never coincided with the overt response (step 5). If the baseline-corrected partial peak force (step 4) was larger than the threshold value (step 3) and occurred within the predetermined window (step 5), it was categorized as a partial response and included in the PR analysis.

Statistics

In order to control for handedness and applied force differences between both responses, RTs, RF and force of PRs were standardized within participants for each response separately. Mixed effects models (Baayen, Davidson, & Bates, 2008) were used to investigate the relationship between RTs, RF and PRs. Price condition was included in as numerical predictor (i.e., $\pm 70\%$, $\pm 40\%$, $\pm 10\%$ and retail) in all models. The 'lme4' package (Bates, Mächler, Bolker, & Walker, 2014) in RStudio (R Core Team, 2018) was used to fit the models. By-participant and by-product random intercepts were included in order to control for interindividual and interproduct differences. The optimal random slopes structure was determined using a backwards selection procedure (Matuschek, Kliegl, Vasishth, Baayen, & Bates, 2017). For RTs and RF, P-values were calculated using Satterthwaite approximated degrees of freedom. Beta coefficients β will be provided as effect size measures. To investigate differences in PR frequency, we used model comparison procedures to determine statistical significance.

Manipulation check

In order to test whether the price manipulation had the anticipated effect, a logistic mixed effects model was fitted to investigate if price evaluations (cheap or expensive) were modulated by price condition ($\pm 70\%$, $\pm 40\%$, $\pm 10\%$ and retail). The model also incorporated random intercepts for the participant and product effects. The effect of price condition was indeed significant ($\chi^2(1, 4) = 5458$, $p < .001$) and therefore it was concluded that participants perceived the magnitudes of prices as anticipated. Overall, if prices were either clearly 'cheap' or 'expensive', this resulted in more cheap and expensive evaluations. When the prices were

expected to be perceived as ambiguous there was a smaller difference between the absolute frequencies of both price evaluations. Across price conditions, the percentages of 'cheap' responses were distributed as follows: -70% (96%), -40% (75%), -10% (45%), retail (38%), +10% (31%), +40% (16%), and +70% (6%).

Results

Reaction time analysis

A quadratic mixed analysis was performed to test the relationship between RTs and price condition. The model included price condition (i.e., $\pm 70\%$, $\pm 40\%$, $\pm 10\%$ and retail) as numerical predictor and by-participant and by-product random intercepts and random slopes to model the intraindividual effect of price condition. The results revealed a significant linear, ($t(11.15) = 7.22$, $\beta = .26$, $\beta SE = .04$, $p < .001$), as well as quadratic effect of price condition, ($t(11034.64) = -15.58$, $\beta = -.04$, $\beta SE = .003$, $p < .001$), indicating that RTs followed a reversed U-shaped pattern. Figure 2 further shows increased standardized RTs for the ambiguous price conditions, with a peak at the -10% price condition, in comparison with the unambiguous price conditions.

Figure 2. visualization of the effect of price condition on the averaged RTs.

Response force analysis

A quadratic mixed model on the RF was performed with price condition as numerical predictor as well as random intercepts for participants and products. Both the linear, ($t(11063.70) = -2.99$, $\beta = -.07$, $\beta SE = .02$, $p = .003$), and quadratic, ($t(11063.69) = 2.79$, $\beta = .01$, $\beta SE = .004$, $p = .005$), main effect of price condition were significant, and showed a trend in the expected direction. That is, RF followed a U-shaped pattern with decreasing RFs from -70% to retail and increasing RFs from retail to +70%, with the exception of the +40% price condition. Figure 3 graphically depicts the standardized RF across price conditions.

Figure 3. Visualization of the effect of price condition on the averaged response force.

Partial response analysis

Frequency

A logistic mixed model was fitted on the presence of PRs in trials (present or absent) with price condition as a numerical predictor and by-product and by-participant variability included as random intercepts. We tested whether this model significantly contributed to a model which did not include price condition. Results showed that price condition did not significantly affect the PR frequency ($\chi^2(6, 9) = 10.34, p = .11$). Figure 4 shows the percentage of partial responses for each price condition when averaged over responses. Hence, the frequency of PRs did not differ depending on the price condition. Overall, we found very little partial responses (5.18% of all trials).

Figure 4. Percentage of partial response observed in each price condition.

Partial response force

A quadratic mixed model on the Z-standardized partial peak force was performed with price condition as a fixed predictor and random intercepts for both participants and products. The main effect for the linear price condition was not statistically significant, ($t(558.36) = -0.15$, $\beta = -.02$, $\beta SE = .10$, $p = .88$), as well as the quadratic term of price condition, ($t(563.97) = 0.44$, $\beta = .01$, $\beta SE = .02$, $p = .66$). Figure 5 shows the averaged standardized PR force across price conditions.

Figure 5. visualization of the effect of price condition on the averaged partial response force.

Relationship between RTs and RF

To establish the relationship between RF and RTs on a trial-by-trial level, we conducted a linear mixed model on the standardized RF with the standardized RTs as numerical predictor. Furthermore, the model for the overt peak force incorporated random intercepts for participant and product. We found that RTs significantly predicted the overt peak force ($t(11069.99) = 2.81$, $\beta = .04$, $\beta SE = .01$, $p < .01$). For the partial peak force, besides having Z-standardized RTs as a fixed predictor, the random effects structure consisted of a by-response intercept and slope for both effects of participants and products. Our results yielded a significant effect for RTs ($t(526.50) = 5.86$, $\beta = .32$, $\beta SE = .06$, $p < .001$).

Discussion

In the current paper, we investigated whether consumers' WTP could be measured implicitly by indexing reaction times (RTs), response force (RF) and partial responses (PRs) during a price evaluation task. Overall, our results indicated that both RTs and RF might be dependent measures that can be used to estimate WTP. To this end, we consider the evidence provided in this paper as the starting point in the development of implicit WTP estimation procedures. On the other hand, PRs did not seem to provide any useful information about WTP and are therefore considered as unlikely to be a valuable as an implicit measure of WTP.

The obtained RT data exhibited the expected 'n-shaped' pattern over price conditions, indicated by the significant main effect for both price condition and its quadratic term. This suggests that the increased RTs observed in ambiguous price conditions (retail, $\pm 10\%$), compared to the unambiguous price conditions ($\pm 40\%$, $\pm 70\%$), are the result of both response tendencies competing to be selected ('cheap' versus 'expensive') because ambiguous prices more closely relate to participants' IRP (i.e. the price stimulus is neither undoubtedly cheap or expensive). This potentially causes mutual disruption whereby the overt response is less easily activated, resulting in longer RTs. Following this reasoning, the price corresponding with highest RT (i.e. -10% price point), is the price that is located the closest to the consumers' IRP. Analysis of the RF data portrayed the anticipated 'U-shaped' pattern where ambiguous prices led to less forceful responses compared to unambiguous prices. Hence, as price conditions became less ambiguous, RF increased accordingly. Generally, it seems that the RF reflects the degree of confidence associated with the response. Prices that are undoubtedly 'cheap' or 'expensive' yield clear evidence in favor of a particular response, which in turn promotes forceful responses. Here, the price corresponding to the most doubt (i.e. the lowest

RF value) should reflect the optimal prices. This is because the consumers were not sure whether the price was 'cheap' or 'expensive', and therefore it is likely that this price is more or less aligned with the internal reference price (i.e. retail price condition). Hence, both RTs and RF seem to be distinguishable measures that could be used to determine the optimal selling price of a product. Interestingly, both measures point towards a different optimal price point (i.e. -10% and retail price). This might imply that both measures provide divergent information and therefore reflect other aspects of the price evaluation process. Future studies need to investigate whether RTs and RF indeed provide valid estimates and if the information from both variables is divergent.

Third, we predicted that especially for the ambiguous price conditions each response would initially receive some motor activation until one response eventually dominates the response competition. Price stimuli that elicit activation for both options should therefore also co-activate the competing response to a relatively lesser degree. Due to this ambivalence, we anticipated that for ambiguous price conditions partial responses should be more frequent as the partial response would receive sufficient motor activation to become apparent in the participants' action dynamics. This would imply that the incidence of partial responses signifies uncertain price evaluations. However, the obtained results do not provide evidence this premises. As can be seen in Figure 4, the frequency of the partial responses remained fairly constant across the price spectrum. Furthermore, results for the partial peak force showed no significant effect for price condition and did not exhibit the anticipated increase for the ambiguous prices. There are at least three possibilities why partial responses did not vary across price conditions. Most importantly, it is possible that competition takes place at more preparatory levels and that only in a few instances this is manifested at the motor output level. Secondly, it could be that our measure of partial response force is

deficient as no constant force had to be applied on the buttons of the response box. Therefore, participants were required to build up the force in order to respond thereby potentially increasing the threshold to respond, which would be unfavorable particularly for partial responding. Lastly, the price stimuli in itself might evoke little conflict between both response options and is therefore not suited to discriminate between different price conditions.

Another interesting finding is that, in sharp contrast to prior research (Englund & R., 2009; Giray & Ulrich, 1993; Schröter, 2007; Stahl & Rammsayer, 2005), there appeared to be a relationship between the overt peak force and RTs. This can, at least partially, be explained by the more sensitive approach that was used compared to the reported correlations. Our results suggest that longer RTs are associated with more forceful responses. Therefore RTs are thought to encompass all processes leading to the final outcome of the decision process (i.e. stimulus identification, activation built-up, response preparation and execution) while RF seems more involved with the degree of confidence in the price evaluation based on the evidence available (confident decisions lead to more forceful responses). Unsurprisingly, this was more pronounced for the partial response force. Possibly because the preparation of an alternative response preceding the dominant response impedes the execution of that response (Coles, Scheffers, & Fournier, 1995; Rochet et al., 2014). However, the time necessary to override this initial response tendency within the motor system is captured by the RT of the overt response. It thus seems that partial responses offer little support in discriminating between prices.

Taking in mind that the purpose of this study was to identify variables that potentially could contribute to the estimation of consumers' WTP, several elements need to be taken into account when interpreting the presented evidence. One important factor is that all

estimates and inferences are based on data aggregated over products, meaning that one cannot generate WTP estimates for the individual products. This choice was made in order to provide sufficient statistical power to measure the effect of interest: the relationship between price ambiguity and the dependent variables (RTs, RF and PRs). Hence, we focused on the effect of the price manipulation across products. In this regard, price conditions were also kept widespread such that price could be either perceived as normal or extremely cheap and expensive, allowing the anticipated effect to emerge. Also, since reaction times only provide an insight in the final outcome of the cognitive processes involved, more thorough analysis of action kinematics could provide an in-depth view of the unfolding evidence-accumulation over time in favor of both responses at the same time. Future work could substantially contribute to this line of inquiry by implementing the paradigm into an EEG-study or by using more advanced analysis techniques such as drift diffusion analysis (Mormann, Malmaud, Huth, Koch, & Rangel, 2011; Wiecki, Sofer, & Frank, 2013). This would also allow a more definitive conclusion as regards the partial response. Also, a condensed price spectrum (e.g. -15, -10%, -5%, retail, +5%, +10%, +15%) would render more specific and realistic predictions as, in practice, a 10% difference between the two measures would imply a significant difference in revenue.

In conclusion, the current study provides some evidence for the notion that both RTs and RF can be fruitful dependent measures to estimate consumers' WTP implicitly. It was investigated whether stated consumer responses in pricing research could be circumvented by the use of alternative dependent measures. We showed that RTs and RF seem to provide valuable information. It is important to note the main contribution of this study is methodological, but that we not introduce 'ready-to-use' procedures. Yet, future research

needs to further investigate how the use of these 'implicit' variables can result in valid WTP estimates.

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