Decision Times in the Luce Model*

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Abstract

We test a new model of decision times based on the decision probabilities of the Luce model of stochastic choice. The model extends the so-called Hick's law of reaction times. According to the model, expected decision times are represented by the Tsallis entropy of the decision probabilities. To test the prediction, we conduct a choice experiment with a value task under risk and time pressure and collect decision times for over 37 000 decisions from household item lotteries. For each subject in our experiment we find a statistically significant rank correlation between Tsallis entropy and decision time. With a mean absolute rank correlation of 0.32, the results are also economically significant, suggesting decision times can be used to detect "difficult" decisions in which the value difference of alternatives is small.

Keywords: Choice Experiments, Decision Times, Luce Model, Stochastic Choice, Tsallis Entropy, Hick's Law

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1 Introduction

The time for an individual to react to a stimulus has a long history of empirical investigation starting with Hirsch (1861-63). Formal models of reaction and decision

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times have for example been proposed by Hick (1952) and Ratcliff (1978).[1] Much more recently, decision times have also attracted the attention of axiomatic decision theorists, for example in the contexts of multialternative choice models (Baldassi et al., 2020) and multiattribute choice models (Koida, 2017). Axiomatic foundations for behavioral models are useful as they provide testable conditions on behavior under which a model is adequate to describe behavior and as they help guiding empirical research.

The present project tests a recent prediction (Rommeswinkel, 2019) on the relation between choice probabilities and decision times in multi-alternative choice: in the context of stochastic choice, a variant of Hick ('s 1952) law holds whenever the decision probabilities follow the Luce (1959) model and decision times are increasing in the decision time of every subdecision. More precisely, according to the prediction decision times are a continuous monotone transformation of the Tsallis (1988) entropy of the decision probabilities.[2]

To test this hypothesis, we performed laboratory choice experiments at the University of Konstanz and Waseda University. We repeatedly offered subjects the decision between four different electric appliances. Each appliance, if chosen, could be won with a probability displayed beneath the item. The winning probabilities decreased with decision time, inducing time pressure. From more than 1000 decisions per subject we estimated a Luce (1959) model which was used to derive decision probabilities allowing us to calculate entropies. We then used a permutation test to test whether the Tsallis entropy for a chosen entropy index of these decision probabilities is indeed rank correlated to the decision times.

We find strong evidence in support of the Luce-Hick model. The null hypothesis of no rank correlation between decision times and Tsallis entropy was rejected for all of our experimental subjects. Generally, for almost all subjects the data has a triangular shape; low entropy decisions are fast while higher entropy decisions are on average slower but may still be fast, i.e., the variance of decision times increases with the entropy. The decisions that are faster than predicted by the entropy increase turn out to exhibit an increased error rate.

We also find little evidence in favor of the original formulation of Hick (1952), which uses the special case of the Shannon entropy instead of the more general Tsallis entropy: for more than half of the subjects a 95% confidence interval around the estimated Tsallis entropy index did not contain the Shannon entropy index.

The paper proceeds as follows. We provide the theoretical background of the study in Section 2. Section 3 provides details about the experiment we performed. Section 4 contains the statistical methods we used and the results we obtained. We relate our results to the empirical literature in Section 5 before concluding in Section 6.

[1] For an overview of the empirical success of these models, see Proctor and Schneider (2018) and Ratcliff et al. (2016)

[2] A brief overview of this result is provided in Section 2 below.

2 Theoretical Background

Luce (1959) characterized in his seminal work a model of stochastic choice that has found widespread use for example in marketing and transportation economics. The model predicts that the relative probability of choosing for example *airfryer* over *blender* is independent of whether a third alternative, let's say *kettle* is available. Concretely, the choice probability $p(x, C)$ of choosing element x from a set C is given by

$$p(x, C) = \frac{\exp(v(x))}{\sum_{y \in C} \exp(v(y))} \tag{1}$$

where $v : \mathcal{X} \to \mathbb{R}$ is interpreted as a utility function on the universe of alternatives $\mathcal{X}$. This model requires an absence of so-called similarity, attraction, and compromise effects (Roe et al., 2001). For example, the presence of a similar alternative, e.g., a *blueblender* could attract additional attention to the *blender*, increasing its choice probability. If an alternative is seen as a compromise between two other alternatives, it may gain a relatively larger proportion of choices when both the other alternatives are available. The Luce model effectively imposes that no such effects are present.

Hick's law predicts that decision times in response to a stimulus are a linear function of the logarithm of the number of stimuli and matching alternatives. Thus, if the decision maker has to respond to n different stimuli and press a matching button to each stimulus, then the average time it takes from receiving a stimulus until making this decision in response is given by the functional form[3] $A \cdot \ln(n)$. Hick (1952) formulated this law motivated by information theory and employed the Shannon (1948) entropy with uniform stimulus probabilities to derive this prediction. The more general hypothesis for non-uniform decision probabilities over an arbitrary choice set C is given by

$$\tau(C) = A \cdot \sum_{x \in C} p(x, C) \ln p(x, C) \tag{2}$$

for arbitrary choice sets C. The relation between Hick's law and the Luce model is not immediately apparent. However, it turns out that these two models have an intricate mathematical relation to each other. Assume that the decision time is a continuous function of the decision probabilities.[4] Assume second, that the Luce model of stochastic choice holds. Finally, assume that the decision time of every choice

[3] The function is sometimes also stated as $A \cdot \ln(n + 1)$, depending on whether one counts inaction as an option. Since in economics inaction is commonly interpreted as one possible action, we omit the addition of 1.

[4] This assumption is commonly made in the context of the drift diffusion model (e.g., Baldassi et al., 2020). Empirical observations are consistent with decision times increasing in how even the choice probabilities are.

problem is increasing in the time it takes to solve any subdecision problem: if it takes longer to resolve the choice between *airfryer* and *blender* than between *powerbank* and *mouse*, then the choice between *airfryer*, *blender*, *kettle* should also take longer than the choice between *powerbank*, *mouse*, *kettle* as long as *kettle* is equally likely to be chosen in both decision problems.

In Rommeswinkel (2019) it is proven that under the above assumptions decision times can be modeled by the Tsallis entropy, of which the Shannon entropy is a special case.

$$\tau(C) = \begin{cases} T\left(-\sum_{x \in C} p(x,C) \ln p(x,C)\right) & r = 1 \\ T\left(1 - \sum_{x \in C} p(x,C)^r\right) & \text{else} \end{cases} \tag{3}$$

where T is a continuous increasing function and r is a positive real parameter. Notice that if T is linear and $r = 1$, we recover equation (2). The main difference is that instead of the Shannon entropy, the decision times follow the Tsallis entropy. Nonetheless, the model remains tractable enough to test it empirically. The axiomatic foundation of the model can be paraphrased as follows:

Theorem 1 (Rommeswinkel (2019))**.** *Suppose decision times are a continuous function of choice probabilities and are increasing in the decision time of subdecisions. Then the decision times are a continuous, monotone transformation of the Tsallis entropy of the choice probabilities.*

The present paper attempts to test this model. The following scenarios are possible. First, it can be the case that average decision times are not increasing in the decision times of subdecisions. Second, it can be the case that average decision times are not a function of decision probabilities. In both cases, the entropy is a too restrictive or even inadequate functional form to model decision times. Third, it can be the case that the decision data does not follow the Luce model to a sufficient degree so that decision probabilities cannot be meaningfully estimated. However, if none of these are the case or violations of these assumptions are sufficiently small, then the Tsallis entropy of the Luce model probabilities should be rank-order correlated with decision times.

3 Experimental Design

Our test subjects make repeated decisions in a value task under risk and under time pressure in which they can win electronic household items. At the end of the experiment, one of the decisions is randomly selected and implemented. The probability of winning a household item depends both on the speed with which the choice is made and the chosen option.

In each decision, subjects are shown four distinct options, positioned symmetrically on the left, top, right, and bottom of the screen. Each option constitutes a lottery of either winning a household item or winning nothing. Under each option is a bar with varying length. The bar displays the probability of receiving the item if the decision is made immediately with zero decision time.

To induce time pressure, we included an additional bar at the center that linearly shrinks with time. This represents an additional binary lottery that the decision maker has to win in order to received the item in the round. This bar affects all options identically. The overall probability of winning is therefore the probability of the chosen option times the probability remaining on the central bar at the time the decision was made.

The participant makes a choice using the arrow keys on a keyboard, the animation of the central bar then freezes, and two triangular indicators appear below the two bars respectively. These indicators slide rightwards to a random position. If *both* indicators overlap with their respective bars, this means the participant wins the item in this decision. If one or none overlaps, the participant does not receive an item. The motion of both indicators is programmed at a non-predictable speed to make the animation reminiscent of a carnival wheel.

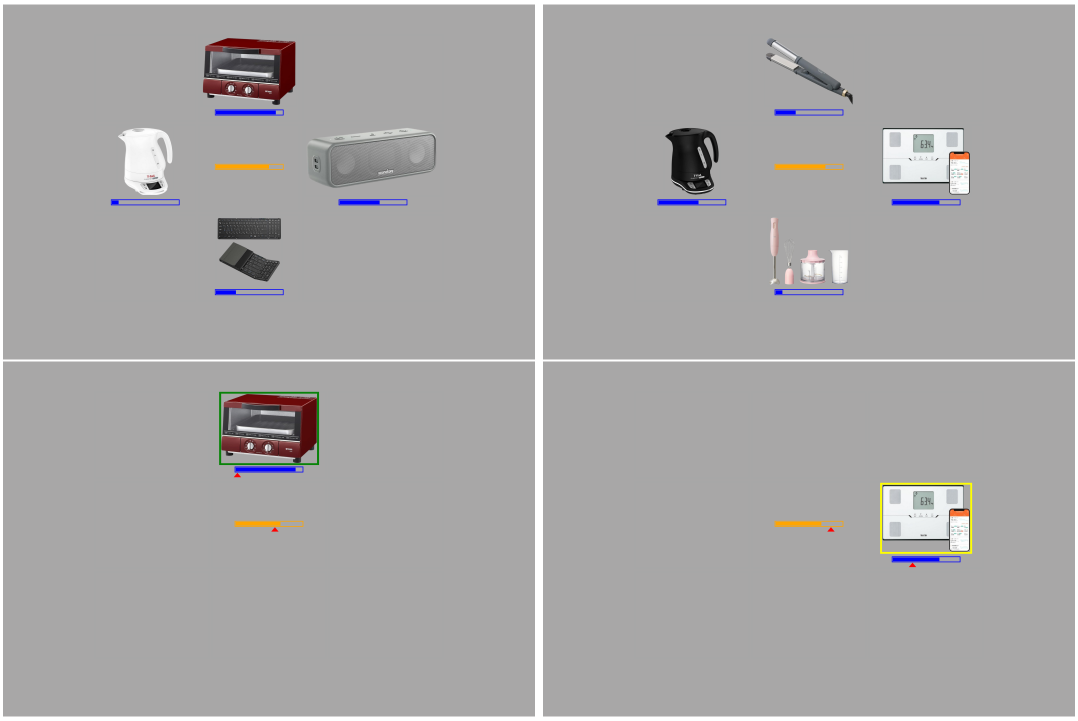


Figure 1: Decision Task of the Experiment showing a winning and a losing decision.

Since the probability of winning each product is a product of the time-dependent probability and the probability of the chosen item, the relative valence of items is unaffected by the speed with which decisions are made; an expected utility maximizer would prefer the resulting lottery of chosen product A over that of product B irrespective of how much time has passed. Our specification of the utility in the Luce model will reflect this property, too.

3.1 Hypotheses

We apply the Luce model of stochastic choice to the decision problems and employ the following notation: $i = 1, 2, 3, 4$ denotes the position of the item on the screen. x_i denotes the household item displayed in position i. q_i denotes the probability visualized by the bar under the product in position i. We assume that the Luce model holds with utility $v(q_i, x_i)$ of a lottery that yields with probability q_i item x_i. In addition, we assume that the probability of choosing i fulfills the following conditions:

Axiom 1 (Monotonicity in Probabilities)**.** The predicted probability of choosing an item is monotonically increasing in the probability of receiving the item.

Axiom 2 (Scale Invariance)**.** For any C such that $(q_i, x_i), (q_j, x_j), (q_i', x_i), (q_j', x_j) \in C$, If $\frac{q_i}{q_j} = \frac{q_i'}{q_j'}$, then $\frac{p((q_i, x_i), C)}{p((q_j, x_j), C)} = \frac{p((q_i', x_i), C)}{p((q_j', x_j), C)}$

We can then use Pexider's functional equation to show that:

Proposition 1 (Lottery Utility Function)**.** *If the stochastic choice function p fulfills equation* (1) *with stochastic utility v, monotonicity in probabilities, and scale invariance, then there exists a utility function u over household items and a positive real valued parameter β such that:*

$$v(q_i, x_i) = u(x_i) + \beta \cdot \ln(q_i) \tag{4}$$

Our theoretical model lead us to the following hypothesis:

Hypothesis 1. For each subject, across decisions, decision times are rank correlated with the Tsallis entropy (given some entropy index) of the decision probabilities.

The corresponding null hypothesis is:

Hypothesis 2. For each subject, across decisions, decision times are rank uncorrelated with the Tsallis entropy (for every entropy index) of the decision probabilities.

While the theoretical considerations do not imply a direction of the correlation, past evidence suggests it is plausible that more difficult decision problems take longer, i.e., if alternatives are closer in value, then decisions take longer. This leads to the following, sharper formulation of the hypothesis:

Hypothesis 3. Decision times are strictly positively rank correlated if the entropy index is positive and strictly negatively rank correlated if the entropy index is negative.

The corresponding null hypothesis is:

Hypothesis 4. For each subject, decision times are negatively correlated if the entropy index is positive and positively rank correlated if the entropy index is negative.

Finally, using our data we can further test whether Hick's law in its original formulation (decision times being linear in the Shannon entropy) holds and/or whether the generalization to the Tsallis entropy provides an improved fit of the data.

Hypothesis 5. The entropy index that maximizes the rank correlation between decision times and entropy is equal to 1.

The alternative hypothesis is:

Hypothesis 6. The entropy index that maximizes the rank correlation between decision times and entropy is different from 1.

3.2 Experimental Procedures

We used oTree (Chen et al., 2016) to conduct the experiment. Two sessions with 10 subjects were held at the University of Konstanz. One session with 20 subjects was held at Waseda University. At the University of Konstanz, subjects were invited via ORSEE (Greiner, 2015). Both at the University of Konstanz and at Waseda University subjects were each divided into equal-sized groups. The number of decisions and items varied across groups according to Table 1.

Before starting the experiment, subjects were shown the list of all available items. The list contained a colored image of each item, together with information of their brands, the names, key functional parameters and sizes. After familiarizing themselves with the items, subjects performed 15 trial rounds of the experiment. The main experiment containing the 1200 - 1400 decisions was then started. Decisions were generated randomly by combining lottery probabilities with alternatives and alternatives were drawn without replacement (but may have different colored versions in the same round).

Subjects at University of Konstanz were allowed to leave early if they completed all decision problems. This was the case for all subjects. For regulatory reasons, this was not permitted for subjects at Waseda University. Subjects were able to pause the experiment after every decision via a pause button.

3.3 Compensation

Subjects received both monetary compensation and possibly an item based on a randomly selected decision.

If subjects did not complete all decision problems after 2 hours, but solved at least 100 decision problems, a random decision of the solved decision problems was implemented. This was the case for one subject at Waseda University.

Group	Session	Subjects	Decisions	Items
1	Konstanz I	5	1300	air purifier (white), fryer (black), kettle (grey), mouse (red), powerbank (white), speaker (blue), toothbrush (black)
2	Konstanz II	5	1400	air purifier (white), fryer (black), kettle (grey), mouse (red), powerbank (white), powerbank (black), speaker (red)
3	Waseda I	10	1200	speaker (blue), speaker (red), powerbank (green), powerbank (blue), earphone (white), earphone (black), blender (white), blender (green), blender (black), blender (pink), airfryer (black), airfryer (white), kettle (blue), kettle (green), kettle (black), kettle (white), keyboard (black), keyboard (white), toothbrush (pink), toothbrush (blue), scale(black), scale(white), toaster (white), toaster (red), straight iron (beige), straight iron (black)
4	Waseda I	10	1200	speaker (grey), kettle(red), powerbank (blue), blender (white), airfryer (black), kettle(blue), kettle (black), straight iron (beige)

Table 1: Group Description: this table exhibits the number of subjects, the number of choice tasks assigned to each person in experiment, and the set of items they choose of the 4 groups of participants recruited at Konstanz University (Germany) and Waseda University (Japan). All items under the same name are of identical type, except the case of kettle, for which we prepare two kinds, one produced by T-fal (black and white) and another by Delonghi (green and blue).

Items were purchased on Amazon and sent to the subject's home. Monetary compensation was made via bank transfer at the University of Konstanz and in cash at Waseda University.

4 Results

We estimate the Luce model by maximum likelihood estimation. We normalize the utility of the first alternative (a black airfryer) to 1. The Luce estimation results are shown in Tables 3-6 in Appendix A. We then use the results of the Luce estimation to derive choice probabilities for every decision problem. From these choice probabilities we can (given an entropy index) calculate the entropy of the decision probabilities.

Item	Konstanz (EUR)	Waseda (JPY)
Show-up fee	3	0
Completion fee	10	2000

Table 2: Compensation Costs: the monetary compensation is divided into a show-up fee and a completion fee for the experiments conducted at Konstanz while is paid in one settlement if the participant completes all designated tasks at Waseda.

Figure **??** shows for each test subject a scatter plot between Tsallis entropy of the decision probabilities (horizontal axis) and the decision time (vertical axis). For almost all subjects there is a clear pattern: decision times increase in the entropy and the variance of decision times increases also for a higher entropy. We suspect that the increase in variance is because subjects sometimes do not deliberate between similarly attractive alternatives when confronted with multiple attractive alternatives. We will return to this observation in more detail later.

Our main hypothesis states that expected decision times are monotone in the Tsallis entropy of decision times *for some entropy index*. This complicates the testing because we are allowed to choose the entropy index to maximize the absolute rank correlation. The results of this estimation are shown in Table B in Appendix B.

Naturally, choosing the entropy index that maximizes the rank correlation renders the standard methods for hypothesis testing invalid. We therefore test our main hypothesis via a permutation test: For each subject, we choose the entropy index that maximizes the logexp of the rank correlation between the decision times and the Tsallis entropy of the estimated Luce choice probabilities. The resulting maximized logexp of the rank correlation is our test statistic. We then generate a large sample of test statistics under the null hypothesis by permuting the decision times (rendering decision times and choice probabilities independent) and recalculating the test statistic. This allows us to obtain the distribution of the test under the null hypothesis and thus calculate p-values for our test statistic. The results are shown in Table **??**.

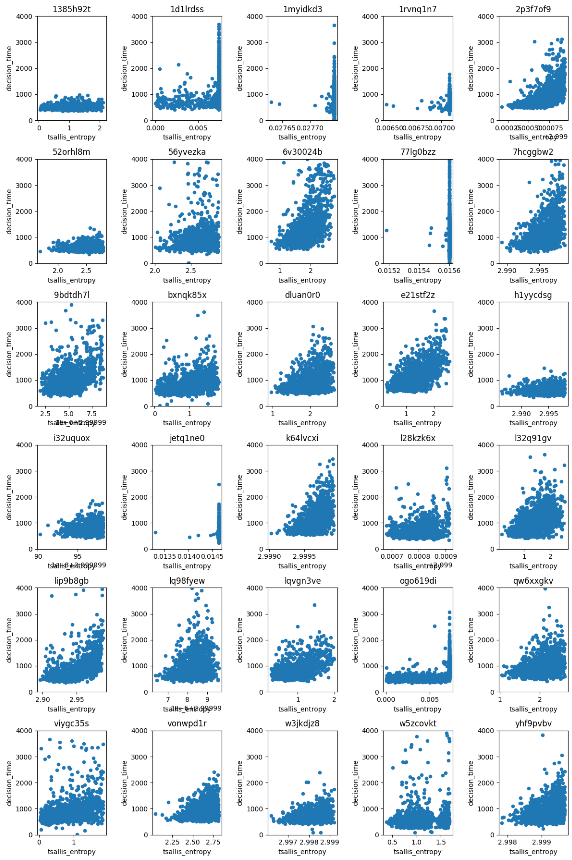


Figure 2: Scatter Plot of Tsallis Entropy and Decision Times

session	participant	Shannon model	Shannon p-value	Tsallis model	Tsallis p-value
1	1myidkd3	0.07	0.01	0.08	0.000
	9bdtdh7l	0.17	0.00	0.34	0.000
	l28kzk6x	0.07	0.01	0.14	0.000
	lqvgn3ve	0.38	0.00	0.40	0.000
	ogo619di	0.69	0.00	0.70	0.000
2	dluanoro	0.37	0.00	0.39	0.000
	lq98fyew	0.18	0.00	0.24	0.000
	w3jkdjz8	0.20	0.00	0.24	0.000
	w5zcovkt	0.20	0.00	0.20	0.000
	yhf9pvbv	0.27	0.00	0.32	0.000
3	1385h92t	0.17	0.00	0.17	0.000
	1d1lrdss	0.43	0.00	0.43	0.000
	1rvnq1n7	0.19	0.00	0.25	0.000
	2p3f7of9	0.65	0.00	0.72	0.000
	56yvezka	0.13	0.00	0.15	0.000
	7hcggbw2	0.45	0.00	0.52	0.000

In addition, for comparison, we have provided the rank correlation of the Shannon entropy model. Already the results on the rank correlation between the Shannon entropy and the decision times is highly statistically significant for all except two subjects. Once choosing the entropy index of the Tsallis entropy, the Tsallis entropy and the decision times are rank correlated to decision times for all subjects at high statistical significance. We therefore reject the null hypothesis (H2) that decision times are not a monotone function of the Tsallis entropy of the Luce model choice probabilities in favor of H1.

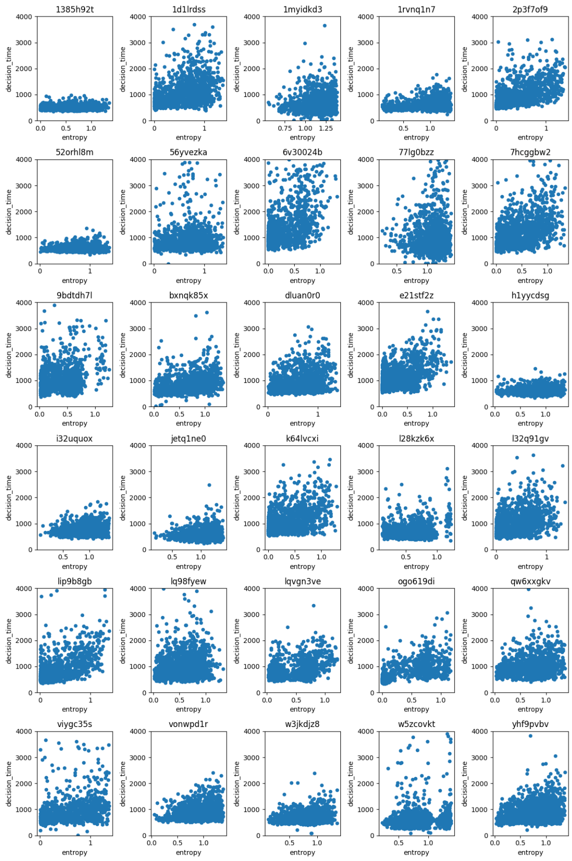


Figure 3: Scatter Plot of Shannon Entropy and Decision Times

We show the scatter plots with respect to the Shannon entropy in Figure 3. As we can see, even if we do not choose the entropy index freely, the entropy of choice probabilities exhibits a strong relation with decision times. For the two subjects where the rank correlation is not significant, it appears that the variance increase associated with a higher choice entropy partly dominates the increase in average decision times.

The "triangular" pattern visible in the scatter plots for both Tsallis and Shannon entropy leads to the natural question whether the decisions in the lower right corner (that are fast and have a high entropy of decision probabilities) are different from the decisions along the diagonal (that are fast in case of a low entropy and slow in case of a high entropy). To investigate this, we look at the error rate of the decisions, i.e., the rate with which an item is chosen that does not maximize v among the available options. We classify decisions as *fast decisions* if the residual error of a linear regression of decision time on the Shannon entropy of the choice probabilities is at least 1.5 standard deviations. A decision is classified as *regular* if its residual error is within 1.5 standard deviations from zero. For the fast decisions we find an error rate of 0.42 while for regular decisions we find an error rate of 0.25 across all decision makers. This suggests that the fast decisions may arise from decision makers prioritizing speed over accuracy for some decisions or behaving in a satisficing manner of quickly choosing an alternative that appears good enough.

Finally, we find that a 95% confidence interval (obtained from bootstrapping) around the optimal Tsallis entropy index contains the Shannon case ($r = 1$) for less than half of all subjects. Though not a proper statistical test, this provides tentative evidence in favor of H6 over H5; at least in our data, there is nothing special about the Shannon entropy versus any other entropy index. Since our model is derived from relatively innocuous assumptions on the relation between decision times and choice probabilities, it would be interesting to revisit past data to see whether the evidence in favor of Hick's law is just a byproduct of Theorem 1.

5 Relation to Literature

Decision and reaction times have been tested emprically using binary motion discrimination tasks (Drugowitsch et al., 2012; Ratcliff & McKoon, 2008), consumption choices (Ashby et al., 2016; Clithero, 2018; Krajbich & Rangel, 2011; Krajbich et al., 2012; Reutskaja et al., 2011) reactions to light bulbs (Brainard et al., 1962; Hick, 1952; Hyman, 1953; Kornblum, 1969), and to numbers (Brainard et al., 1962; Kornblum, 1969). These can more broadly be classified into perceptual tasks (binary motion discrimination, light bulbs, and numbers) and value tasks (consumption choices). A detailed overview of past decision time experiments is provided in Appendix F.

Krajbich and Rangel (2011) extend the binary drift-diffusion model to three alternatives via a stopping time at which the difference in perceived value between an alternative and the second best alternative reaches a threshold. They find that this model predicts fixation times well.

Our experiment combines features from several different papers. Like Krajbich et al. (2012), we use the value task of choosing between electric consumer items. Like Krajbich and Rangel (2011), we use multialternative choice. Like Drugowitsch et al. (2012), Kornblum (1969), Milosavljevic et al. (2010), Ratcliff and McKoon (2008), and Reutskaja et al. (2011), we employ decisions under time pressure. Like Brainard et al. (1962), Hyman (1953), Kornblum (1969), and Krajbich et al. (2012), we are interested in testing Hick's law. Like Shevlin et al. (2022), we connect the Luce/logit model with decision times; while Ashby et al. (2016) studies how high and low value tasks differ, we focus on the conceptual connection between the Luce model and decision times.

A novel aspect in context of decision time experiments is that we use probabilities of receiving an item to generate additional value variation and (via a time-decreasing probability) induce time pressure.

Our model and predictions rely on simple behavioral axioms. Unlike a large proportion of the literature, we do not use the drift diffusion model to generate predictions. The binary drift diffusion model is compatible with our model given a suitably chosen monotone transformation of decision times between two items. It remains an open theoretical question which multi-alternative extensions of the drift diffusion model are compatible with our Tsallis entropy model of decision times.

6 Conclusion

We find strong support for an intricate relation between a variant of Hick's law and the Luce model of stochastic choice. The Luce-Hick model we found evidence for provides a new way of modeling decision times in multialternative choice and is compatible with the predictions of the drift-diffusion model for binary choice. We hope our research provides guideposts for finding extensions of the drift diffusion model for multialternative choice, a research question discussed in Ratcliff et al. (2016).

For many subjects, we find a relatively high rank correlation (up to 0.69) between the entropy of decision probabilities and decision times. This suggests that our model and methodology would also be applicable in contexts where data on fewer decisions is obtained or decision times are noisier. This allows to reduce time pressure and employ more complex decisions in future research.

A Luce Model Estimation Results

Table 3: MLE Estimation Results Session 1

session	participant	toothbrush black	speaker blue	powerbank white	mouse red	kettle grey	airpurifier white	airfryer black	beta	lln	rmsq
1	1myidkd3	0.09 [-0.22, 0.43]	-0.37 [-0.71, -0.02]	-0.76 [-1.09, -0.44]	-0.81 [-1.18, -0.46]	0.62 [0.32, 0.93]	-0.82 [-1.18, -0.51]	1.27 [1.00, 1.53]	1	1455.29	-0.64
	9bdtdh7l	-4.95 [-5.74, -4.29]	-5.51 [-6.27, -4.89]	-3.04 [-3.66, -2.57]	-7.22 [-18.77, -6.41]	-6.20 [-7.35, -5.39]	-0.32 [-0.76, 0.18]	0.87 [0.43, 1.34]	1	474.84	-0.32
	l28kzk6x	-2.31 [-2.80, -1.86]	-2.76 [-3.39, -2.21]	1.60 [1.24, 2.03]	-4.75 [-6.20, -3.87]	-2.69 [-3.30, -2.15]	-0.55 [-0.98, -0.13]	0.65 [0.35, 1.00]	1	776.58	-0.43
	lqvgn3ve	-1.96 [-2.47, -1.51]	-2.76 [-3.33, -2.20]	-3.66 [-4.33, -3.09]	-5.99 [-18.31, -4.99]	-4.92 [-6.11, -4.20]	1.29 [0.86, 1.74]	1.72 [1.30, 2.18]	1	544.63	-0.35
	og0619di	-9.26 [-20.57, -7.70]	-3.44 [-5.07, -2.67]	-3.60 [-5.26, -2.84]	-4.21 [-5.89, -3.50]	-7.94 [-15.86, -6.96]	-6.76 [-8.58, -5.89]	1.97 [1.57, 2.45]	1	415.63	-0.32

Table 4: MLE Estimation Results Session 2

session	participant	speaker red	powerbank white	powerbank black	mouse red	kettle grey	airpurifier white	airfryer black	beta	lln	rmsq
2	dluanoro	5.71 [5.18, 6.33]	1.51 [0.84, 2.08]	1.37 [0.63, 1.90]	7.02 [6.43, 7.77]	2.21 [1.63, 2.77]	3.35 [2.84, 3.86]	5.05 [4.58, 5.58]	1	805.84	-0.43
	lq98fyew	2.84 [2.36, 3.31]	-3.57 [-15.81, -2.46]	-0.73 [-1.25, -0.25]	2.45 [2.04, 2.93]	1.10 [0.70, 1.49]	-4.38 [-15.99, -3.16]	3.93 [3.51, 4.41]	1	778.61	-0.42
	w3jkdjz8	5.70 [5.17, 6.35]	6.62 [6.06, 7.31]	6.11 [5.58, 6.78]	4.08 [3.54, 4.73]	3.11 [2.51, 3.78]	3.41 [2.86, 4.04]	2.79 [2.47, 3.15]	1	1097.59	-0.51
	w5zcovkt	-2.39 [-2.81, -1.97]	-2.42 [-2.87, -2.01]	-1.87 [-2.26, -1.55]	-2.27 [-2.67, -1.84]	0.19 [-0.11, 0.51]	-1.55 [-1.90, -1.21]	1.08 [0.80, 1.39]	1	1124.72	-0.51
	yhf9pvbv	4.67 [4.21, 5.14]	1.79 [1.32, 2.30]	1.89 [1.43, 2.32]	3.15 [2.70, 3.60]	3.90 [3.47, 4.32]	4.22 [3.81, 4.62]	5.58 [5.16, 6.03]	1	1062.38	-0.51

Table 5: MLE Estimation Results Session 3

session	participant	toothbrush pink	toothbrush blue	toaster red	toaster beige	straightiron blue	straightiron beige
3	1385h92t	4.88 [4.12, 5.92]	4.96 [4.19, 5.93]	6.07 [5.28, 7.25]	5.84 [5.02, 7.06]	5.17 [4.41, 6.20]	5.04 [4.29, 6.02]
	1d1lrdss	2.17 [1.13, 3.12]	3.18 [2.41, 4.08]	3.18 [2.30, 4.08]	3.22 [2.38, 4.12]	10.33 [9.19, 12.08]	9.57 [8.52, 10.97]
	1rvnq1n7	1.99 [1.47, 2.59]	2.29 [1.72, 2.95]	1.87 [1.31, 2.56]	1.29 [0.69, 2.01]	2.57 [2.05, 3.26]	2.78 [2.30, 3.43]
	2p3f70f9	7.40 [6.46, 13.33]	7.30 [6.36, 13.64]	2.15 [1.10, 7.61]	1.44 [0.02, 7.86]	6.14 [5.26, 12.36]	5.44 [4.59, 11.58]
	56yvezka	4.14 [3.41, 4.97]	3.46 [2.76, 4.34]	4.17 [3.43, 5.00]	4.19 [3.44, 5.09]	3.85 [3.07, 4.70]	3.72 [2.97, 4.55]
	7hcggbw2	-0.47 [-1.73, 0.54]	-1.03 [-2.87, 0.10]	3.52 [2.93, 4.38]	2.98 [2.28, 3.95]	1.54 [0.84, 2.35]	1.23 [0.45, 2.17]
	i32uquox	-1.31 [-1.98, -0.72]	-1.09 [-1.70, -0.54]	0.77 [0.38, 1.25]	0.46 [-0.01, 0.97]	-0.90 [-1.52, -0.31]	-1.07 [-1.72, -0.49]
	k64lvcxi	-0.48 [-11.12, 1.13]	-0.14 [-12.63, 1.67]	6.95 [6.01, 8.57]	7.20 [6.20, 8.91]	8.80 [7.72, 10.69]	8.83 [7.83, 10.66]
	qw6xxgkv	1.28 [0.70, 1.86]	1.65 [1.12, 2.28]	4.50 [3.97, 5.25]	4.29 [3.66, 5.03]	0.19 [-0.53, 0.96]	-0.34 [-1.05, 0.35]
	vonwpd1r	-0.12 [-0.91, 0.56]	-0.13 [-0.84, 0.51]	0.44 [-0.26, 1.07]	0.98 [0.48, 1.56]	2.34 [1.81, 2.91]	2.37 [1.89, 2.89]

session	participant	speaker red	speaker blue	scale white	scale black	powerbank green	powerbank blue	keyboard white	keyboard black
3	1385h92t	5.21 [4.46, 6.23]	5.41 [4.69, 6.47]	5.28 [4.60, 6.31]	5.25 [4.44, 6.34]	5.21 [4.52, 6.27]	5.69 [4.92, 6.81]	5.51 [4.77, 6.70]	5.63 [4.83, 6.84]
	1d1lrdss	5.15 [4.44, 6.07]	5.64 [4.96, 6.63]	3.86 [3.10, 4.75]	3.83 [3.16, 4.71]	4.46 [3.69, 5.38]	5.46 [4.82, 6.39]	5.04 [4.28, 6.01]	4.37 [3.65, 5.29]
	1rvnq1n7	2.98 [2.44, 3.66]	2.13 [1.57, 2.82]	1.41 [0.69, 2.09]	1.36 [0.78, 1.97]	5.10 [4.51, 5.95]	4.98 [4.40, 5.85]	1.20 [0.60, 1.84]	1.05 [0.34, 1.71]
	2p3f70f9	10.71 [9.68, 17.23]	11.72 [10.60, 18.07]	1.67 [0.48, 7.84]	0.93 [-7.55, 6.76]	2.77 [1.76, 9.23]	3.15 [2.14, 9.32]	2.13 [0.71, 8.17]	2.77 [1.85, 8.96]
	56yvezka	6.33 [5.61, 7.30]	6.29 [5.56, 7.21]	3.94 [3.22, 4.77]	4.11 [3.47, 4.92]	5.34 [4.55, 6.28]	6.00 [5.20, 6.99]	3.89 [3.18, 4.65]	3.96 [3.21, 4.87]
	7hcggbw2	6.53 [5.89, 7.59]	5.87 [5.14, 6.88]	4.62 [3.92, 5.61]	4.02 [3.36, 4.91]	7.27 [6.55, 8.37]	6.66 [6.01, 7.80]	0.81 [0.02, 1.56]	1.42 [0.68, 2.26]
	i32uquox	-0.30 [-0.82, 0.24]	-0.11 [-0.69, 0.49]	-0.52 [-1.03, 0.02]	0.36 [-0.10, 0.90]	0.71 [0.23, 1.29]	-0.03 [-0.56, 0.55]	-0.49 [-1.14, 0.01]	-0.39 [-0.95, 0.20]
	k64lvcxi	7.75 [6.70, 9.41]	7.44 [6.42, 9.19]	3.98 [2.87, 5.50]	4.37 [3.38, 5.87]	7.39 [6.37, 9.08]	7.57 [6.60, 9.29]	10.13 [8.97, 12.12]	9.56 [8.54, 11.46]
	qw6xxgkv	1.34 [0.76, 1.96]	0.95 [0.27, 1.58]	1.53 [0.95, 2.22]	1.61 [0.98, 2.33]	0.97 [0.36, 1.65]	1.20 [0.61, 1.78]	-0.97 [-2.18, -0.13]	-0.62 [-1.70, 0.16]
	vonwpd1r	-0.25 [-0.98, 0.39]	0.23 [-0.38, 0.86]	-0.46 [-1.30, 0.24]	-0.20 [-1.02, 0.48]	0.50 [-0.12, 1.08]	0.41 [-0.25, 0.98]	1.57 [1.04, 2.13]	1.31 [0.78, 1.84]

session	participant	kettle white	kettle green	kettle blue	kettle black	earphones black	earphones beige
3	1385h92t	5.66 [4.87, 6.74]	5.50 [4.75, 6.57]	5.22 [4.44, 6.44]	6.00 [5.19, 7.07]	5.58 [4.83, 6.69]	5.66 [4.90, 6.77]
	1d1lrdss	5.75 [5.06, 6.73]	3.52 [2.79, 4.46]	3.88 [3.11, 4.84]	5.64 [4.94, 6.59]	3.15 [2.50, 4.13]	2.81 [1.97, 3.78]
	1rvnq1n7	1.59 [1.05, 2.22]	1.72 [1.24, 2.32]	1.97 [1.44, 2.58]	1.47 [0.95, 2.18]	1.72 [1.12, 2.36]	2.43 [1.91, 2.99]
	2p3f70f9	2.25 [1.06, 8.69]	5.15 [4.26, 11.12]	5.52 [4.68, 11.81]	3.98 [3.14, 10.12]	9.41 [8.39, 15.47]	7.31 [6.28, 13.46]
	56yvezka	4.46 [3.78, 5.22]	3.93 [3.20, 4.73]	3.94 [3.12, 4.79]	4.36 [3.62, 5.20]	5.34 [4.56, 6.24]	5.08 [4.29, 5.93]
	7hcggbw2	1.51 [0.83, 2.33]	-1.13 [-2.87, -0.12]	-0.21 [-1.40, 0.76]	1.06 [0.17, 1.92]	4.22 [3.54, 5.11]	4.80 [4.12, 5.72]
	i32uquox	0.87 [0.37, 1.47]	1.34 [0.89, 1.93]	1.03 [0.53, 1.62]	1.78 [1.29, 2.35]	0.34 [-0.17, 0.89]	-0.55 [-1.09, 0.01]
	k64lvcxi	2.85 [1.75, 4.16]	2.36 [1.05, 3.82]	2.23 [1.11, 3.49]	2.86 [1.58, 4.33]	8.81 [7.75, 10.61]	9.14 [8.07, 11.04]
	qw6xxgkv	2.77 [2.29, 3.39]	0.30 [-0.35, 0.98]	0.91 [0.24, 1.49]	2.61 [2.10, 3.21]	-0.30 [-1.08, 0.44]	-0.90 [-1.80, -0.20]
	vonwpd1r	0.89 [0.33, 1.47]	0.72 [0.05, 1.29]	0.64 [-0.00, 1.21]	0.73 [0.09, 1.30]	2.68 [2.14, 3.35]	3.43 [2.95, 4.08]

session	participant	blender pink	blender green	blender blue	blender beige	airfryer white	airfryer black	beta	lln	rmsq
3	1385h92t	5.35 [4.67, 6.46]	4.86 [4.14, 6.00]	5.57 [4.78, 6.69]	5.20 [4.55, 6.28]	5.68 [4.94, 6.73]	5.57 [5.00, 6.46]	1	744.62	-0.45
	1d1lrdss	2.22 [1.34, 3.10]	3.62 [2.99, 4.56]	3.77 [3.14, 4.71]	4.29 [3.56, 5.20]	2.59 [1.71, 3.59]	2.79 [2.50, 3.24]	1	732.81	-0.44
	1rvnq1n7	1.62 [1.01, 2.31]	1.72 [1.22, 2.41]	1.95 [1.39, 2.61]	1.30 [0.71, 1.94]	0.94 [0.20, 1.62]	1.35 [1.20, 1.52]	1	1154.85	-0.59
	2p3f70f9	2.00 [0.87, 7.96]	2.15 [1.13, 8.54]	2.38 [1.39, 8.44]	2.40 [1.32, 8.63]	0.63 [-7.01, 6.51]	1.03 [0.84, 1.26]	1	516.56	-0.36
	56yvezka	3.98 [3.17, 4.88]	3.54 [2.80, 4.35]	3.86 [3.19, 4.57]	4.09 [3.34, 4.97]	4.03 [3.21, 4.77]	4.37 [3.97, 4.97]	1	790.22	-0.46
	7hcggbw2	-2.67 [-15.51, -1.13]	-2.91 [-15.41, -1.25]	-2.10 [-16.03, -0.74]	-1.85 [-11.28, -0.63]	2.02 [1.25, 2.90]	1.58 [1.39, 1.88]	1	594.11	-0.39
	i32uquox	-1.45 [-2.20, -0.86]	-1.00 [-1.58, -0.41]	-1.24 [-2.00, -0.68]	-1.12 [-1.67, -0.53]	0.78 [0.34, 1.33]	1.78 [1.62, 2.00]	1	1125.30	-0.58
	k64lvcxi	1.34 [-0.41, 2.74]	1.10 [-0.50, 2.60]	2.48 [1.12, 3.95]	2.19 [0.82, 3.67]	1.67 [0.01, 3.50]	3.01 [2.74, 3.48]	1	518.79	-0.36
	qw6xxgkv	1.65 [1.10, 2.32]	1.77 [1.25, 2.34]	1.50 [0.95, 2.13]	1.80 [1.30, 2.38]	2.67 [2.17, 3.34]	2.70 [2.46, 3.04]	1	868.68	-0.49
	vonwpd1r	2.81 [2.29, 3.39]	2.62 [2.11, 3.25]	2.55 [2.09, 3.17]	2.13 [1.63, 2.73]	1.79 [1.31, 2.38]	1.62 [1.46, 1.84]	1	1070.59	-0.56

Table 6: MLE Estimation Results Session 4

session	participant	straightiron beige	speaker red	speaker grey	powerbank blue	kettle blue	kettle black	blender beige	airfryer black	beta	lln	rmsq
4	52orhl8m	3.41 [2.93, 4.03]	3.25 [2.74, 3.87]	3.08 [2.57, 3.66]	3.74 [3.16, 4.38]	3.57 [3.08, 4.17]	4.03 [3.52, 4.68]	3.42 [2.91, 3.99]	3.60 [3.20, 4.10]	1	757.63	-0.53
	6v30024b	-1.76 [-3.37, -0.92]	8.59 [7.59, 9.95]	8.54 [7.60, 9.86]	0.25 [-0.71, 1.07]	2.64 [2.02, 3.30]	6.73 [5.96, 7.80]	1.20 [0.35, 1.91]	4.38 [3.87, 5.08]	1	396.94	-0.31
	77lg0bzz	1.53 [1.22, 1.92]	2.68 [2.33, 3.04]	1.52 [1.19, 1.86]	1.89 [1.57, 2.24]	1.45 [1.10, 1.82]	1.76 [1.44, 2.10]	1.29 [0.96, 1.68]	1.73 [1.52, 1.96]	1	1285.37	-0.61
	bxnqk85x	2.71 [2.21, 3.25]	6.96 [6.30, 7.80]	6.54 [5.94, 7.30]	3.83 [3.32, 4.42]	3.22 [2.72, 3.77]	3.58 [3.13, 4.11]	2.82 [2.29, 3.39]	3.14 [2.82, 3.60]	1	727.47	-0.44
	e21stf2z	7.23 [6.32, 8.36]	11.77 [10.43, 13.48]	11.37 [10.12, 13.05]	12.50 [11.15, 14.23]	5.29 [4.47, 6.24]	5.86 [5.08, 6.91]	4.53 [3.44, 5.53]	4.76 [4.19, 5.57]	1	404.68	-0.32
	h1yycdsg	3.07 [2.69, 3.53]	4.62 [4.17, 5.20]	3.68 [3.27, 4.21]	3.34 [2.92, 3.81]	3.27 [2.83, 3.79]	3.62 [3.19, 4.12]	3.04 [2.61, 3.53]	3.11 [2.83, 3.46]	1	1019.43	-0.54
	jetq1neo	2.22 [1.91, 2.59]	1.81 [1.49, 2.20]	1.94 [1.62, 2.30]	2.44 [2.13, 2.86]	2.38 [2.07, 2.77]	2.41 [2.12, 2.80]	3.41 [3.08, 3.82]	1.86 [1.68, 2.06]	1	1234.23	-0.61
	l32q91gv	-1.34 [-2.10, -0.75]	2.43 [2.01, 2.97]	3.13 [2.70, 3.72]	-0.68 [-1.32, -0.08]	0.31 [-0.16, 0.83]	-0.21 [-0.76, 0.29]	3.51 [3.03, 4.13]	5.36 [4.89, 5.99]	1	499.13	-0.36
	lip9b8gb	-4.22 [-5.13, -3.63]	-1.86 [-2.24, -1.50]	-1.43 [-1.75, -1.08]	-2.77 [-3.22, -2.32]	-4.25 [-5.22, -3.58]	-4.07 [-4.82, -3.51]	4.08 [3.49, 5.05]	0.92 [0.71, 1.21]	1	421.95	-0.30
	viygc35s	1.88 [1.37, 2.42]	7.39 [6.58, 8.39]	6.71 [5.96, 7.68]	2.54 [2.08, 3.12]	1.93 [1.36, 2.50]	2.50 [2.03, 3.06]	1.56 [0.96, 2.11]	2.34 [2.06, 2.72]	1	596.55	-0.39

B Entropy Index Estimation Results

		Tsallis' q
session	participant	
1	1myidkd3	37.04, (177.86), [0.00, 129.06]
	9bdtdh7l	0.00, (0.00), [0.00, 0.00]
	l28kzk6x	0.00, (0.00), [0.00, 0.02]
	lqvgn3ve	0.39, (0.07), [0.23, 0.50]
	0g0619di	138.20, (562.24), [0.00, 148.35]
2	dluanor0	0.16, (0.31), [0.00, 0.37]
	lq98fyew	0.00, (0.00), [0.00, 0.00]
	w3jkdjz8	0.00, (0.00), [0.00, 0.07]
	w5zcovkt	0.73, (2.47), [0.00, 39.58]
	yhf9pvbv	0.00, (0.00), [0.00, 0.05]
3	1385h92t	0.41, (0.44), [0.05, 2.09]
	1d1lrdss	136.73, (404.83), [0.14, 148.33]
	1rvnq1n7	142.26, (18.40), [95.34, 147.30]
	2p3f70f9	0.00, (0.00), [0.00, 0.02]
	56yvezka	0.05, (0.21), [0.00, 136.68]
	7hcggbw2	0.00, (0.00), [0.00, 0.08]
	i32uquox	0.00, (0.00), [0.00, 107.36]
	k64lvcxi	0.00, (0.00), [0.00, 0.02]
	qw6xxgkv	0.15, (0.43), [0.00, 0.37]
	vonwpd1r	0.07, (0.16), [0.00, 145.16]
4	520rhl8m	0.08, (0.33), [0.00, 139.05]
	6v30024b	0.09, (0.07), [0.01, 0.18]
	77lg0bzz	65.09, (102.47), [0.19, 139.39]
	bxnqk85x	0.59, (0.53), [0.28, 51.86]
	e21stf2z	0.18, (0.04), [0.10, 0.23]
	h1yycdsg	0.00, (0.00), [0.00, 4.59]
	jetq1ne0	69.34, (349.24), [0.00, 107.13]
	l32q91gv	0.19, (0.06), [0.10, 0.33]
	lip9b8gb	0.00, (0.01), [0.00, 0.11]
	viygc35s	0.58, (0.62), [0.25, 73.87]

The confidence intervals for the entropy index were obtained by resampling without replacement. We resampled without replacement since rank correlation coefficients can be sensitive to ties in the data that would be generated by sampling with replacement.

C Instructions

In this experiment, you will make a sequence of many choices between different items. All items are electric household appliances. We will call every time that you make a choice a *decision*. Choosing an item means that with some probability you will receive this item at the end of the experiment. To receive an item, you need to win the item in a decision and this decision must be randomly picked at the end of the experiment. Only one decision will be randomly picked and only for this decision you can receive an item. If in this decision you won an item, you will receive that item.

Choosing an item

In every decision there are four options displayed on the top, left, right, and bottom of the screen. Each option consists of a picture of the item and a bar graph beneath the item. The picture shows the item that can be won. The bar indicates the probability with which the item can be won. The bar becomes smaller as time progresses.

You choose between the items by pressing the arrow keys on the keyboard. Pressing up chooses the top item, pressing right chooses the right item, pressing left chooses the left item, and pressing down chooses the bottom item.

Winning an item in a decision

After you make a choice, it is resolved whether for this particular decision you win the chosen item or not. An indicator is placed with equal probability anywhere on the bar. If the indicator overlaps with the bar, you win the item for this decision. If the indicator does not overlap with the bar, you do not win the item for this decision.

Receiving an item

At the end of the experiment, a decision is randomly picked out of all decisions. If you won an item in that decision, we will order the item for you. If you did not win an item in that round, you will receive no item. The item can be picked up two weeks after the experiment. You will be notified via email where you can pick up your item. Returning the item you received in exchange for money is not possible.

D Comprehension Questions

- How many items can you win in this experiment?
  - You will win exactly one item.
  - You will win one or no item.
  - You will win one item for every round.
  - You will win one item for every round in which you won.
- When will you find out whether you win in a particular round?
  - At the end of the experiment.
  - At the end of the round.
  - Never.
- The probability of winning in a round...
  - ...is always the same in every round and every item.
  - ...is always the same for every item.
  - ...depends on the size of the bar below an item.
  - ...differs across items but not across rounds.
- You can choose an item with a low probability bar to make it more likely to receive other items.
  - True.
  - False.
- The bar that displays the probability...
  - decreases over time.
  - stays the same over time.
  - increases over time.
  - may increase or decrease over time.
- If you win the item...
  - ...you will receive it immediately after the experiment.
  - ...you can later return the item in exchange for money.
  - ...you can pick the item up two weeks after the experiment.
  - ...you will receive the item by mail.

E Experiment Screenshots

In the following, the reader can find the full size screenshots of the sample experiment webpages in Japanese. Longer pages (the ones that contain the instructions, the item descriptions, and a brief feedback after the practice round) are placed at the end. Except from the cases mentioned above, the screenshots are listed in chronological order.

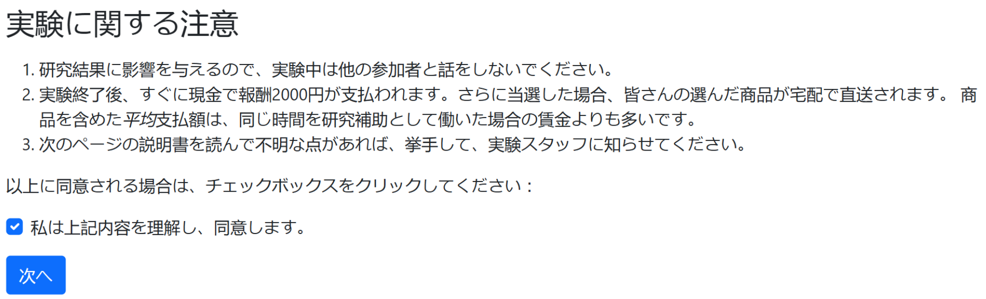
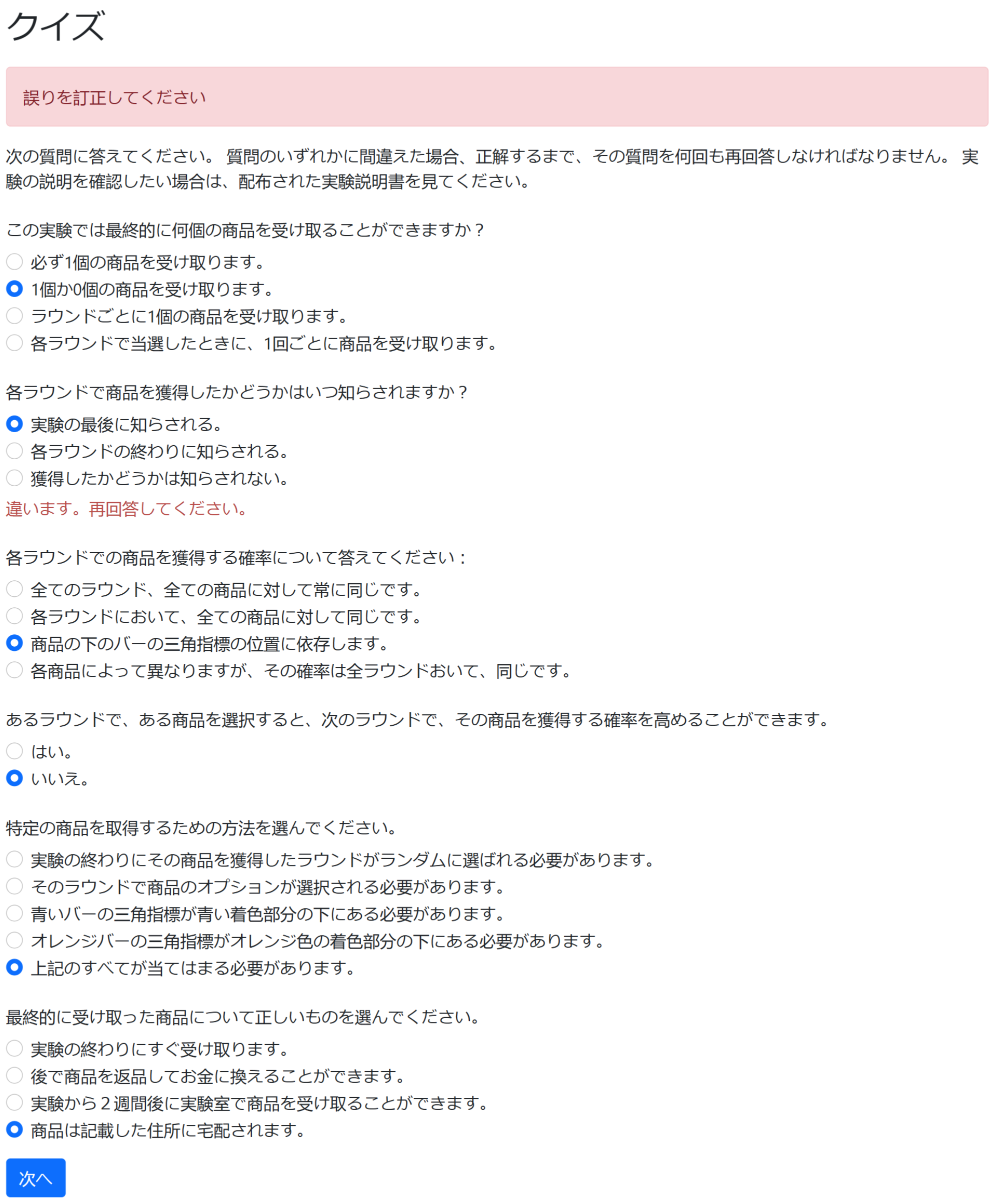


Figure 4: Welcome: this page states the lab requirements and compensations and by giving his or her consent through clicking the checkbox, the participant starts the experiment.



クイズ

誤りを訂正してください

次の質問に答えてください。 質問のいずれかに間違えた場合、正解するまで、その質問を何回も再回答しなければなりません。 実験の説明を確認したい場合は、配布された実験説明書を見てください。

この実験では最終的に何個の商品を受け取ることができますか？

- 必ず1個の商品を受け取ります。
- 1個か0個の商品を受け取ります。
- ラウンドごとに1個の商品を受け取ります。
- 各ラウンドで当選したときに、1回ごとに商品を受け取ります。

各ラウンドで商品を獲得したかどうかはいつ知らされますか？

- 実験の最後に知らされる。
- 各ラウンドの終わりに知らされる。
- 獲得したかどうかは知らされない。

違います。再回答してください。

各ラウンドでの商品を獲得する確率について答えてください：

- 全てのラウンド、全ての商品に対して常に同じです。
- 各ラウンドにおいて、全ての商品に対して同じです。
- 商品の下のバーの三角指標の位置に依存します。
- 各商品によって異なりますが、その確率は全ラウンドおいて、同じです。

あるラウンドで、ある商品を選択すると、次のラウンドで、その商品を獲得する確率を高めることができます。

- はい。
- いいえ。

特定の商品を取得するための方法を選んでください。

- 実験の終わりにその商品を獲得したラウンドがランダムに選ばれる必要があります。
- そのラウンドで商品のオプションが選択される必要があります。
- 青いバーの三角指標が青い着色部分の下にある必要があります。
- オレンジバーの三角指標がオレンジ色の着色部分の下にある必要があります。
- 上記のすべてが当てはまる必要があります。

最終的に受け取った商品について正しいものを選んでください。

- 実験の終わりにすぐ受け取ります。
- 後で商品を返品してお金に換えることができます。
- 実験から２週間後に実験室で商品を受け取ることができます。
- 商品は記載した住所に宅配されます。

次へ

Figure 5: A page that tests the participant's understanding of the experiment: this page includes six questions based on the instructions given to the participants in the previous page. To proceed, participants must answer all of them correctly. Mistakes, if any, will be flagged accordingly and a warning will appear at the top (as shown by the screenshot).

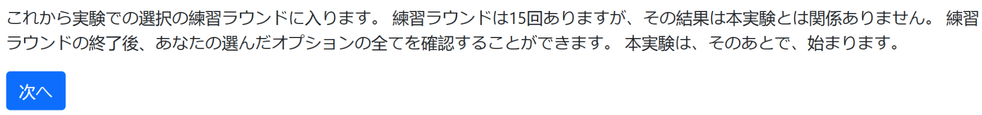


Figure 6: Transition: this page states explicitly the number of decisions in the practice round and that participants could review all of their choices att the end. Participants understand that the practice round does not influence the final compensation.

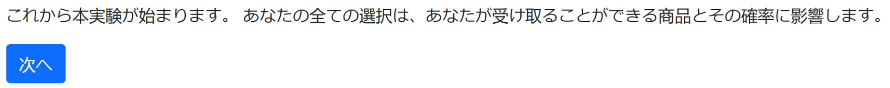


Figure 7: Another transition page before entering the experiment.

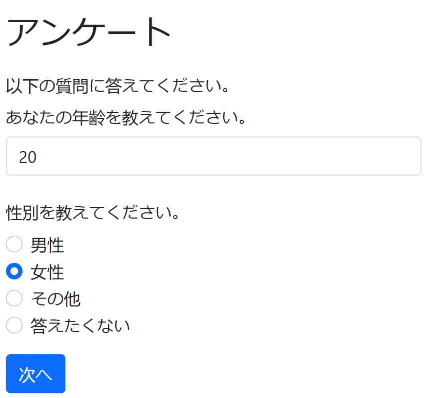


Figure 8: Survey: this page collects demographic information (the age and the gender) from the participants.

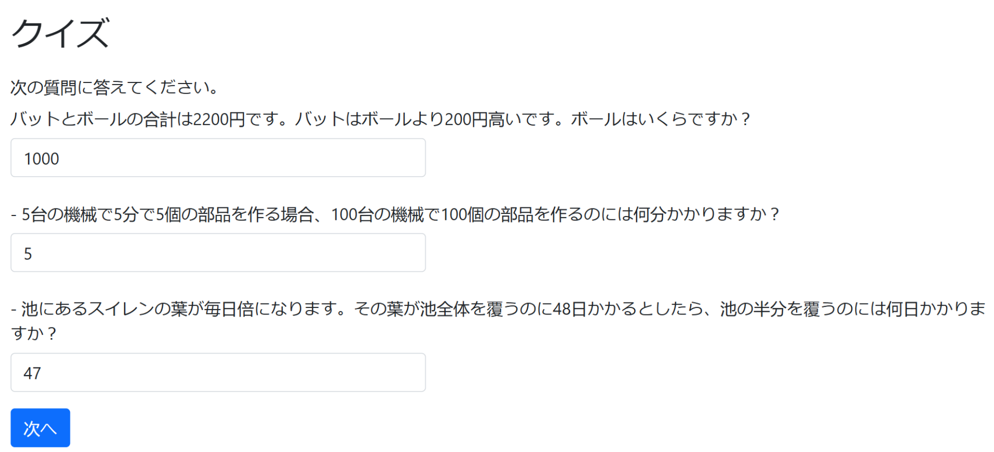
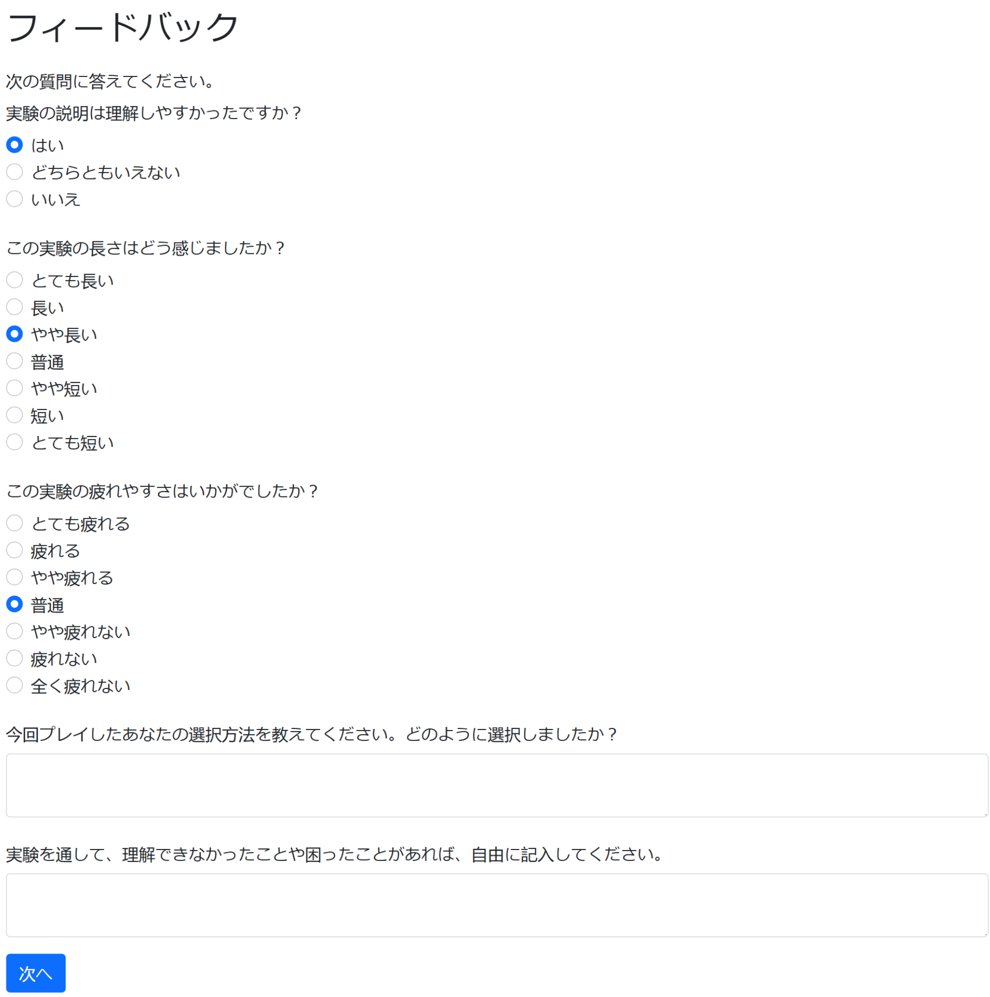


Figure 9: Cognitive Reflection Test: this page presents three brief assessment questions.



フィードバック

次の質問に答えてください。

実験の説明は理解しやすかったですか？

- はい
- どちらともいえない
- いいえ

この実験の長さはどう感じましたか？

- とても長い
- 長い
- やや長い
- 普通
- やや短い
- 短い
- とても短い

この実験の疲れやすさはいかがでしたか？

- とても疲れる
- 疲れる
- やや疲れる
- 普通
- やや疲れない
- 疲れない
- 全く疲れない

今回プレイしたあなたの選択方法を教えてください。どのように選択しましたか？

実験を通して、理解できなかったことや困ったことがあれば、自由に記入してください。

次へ

Figure 10: Feedback: this page asks about the participants' opinions towards the instructions, the experiment duration, how fatigue they are reaching this point, their strategy in decision-making, as well as any difficulty they have found in the past tasks.

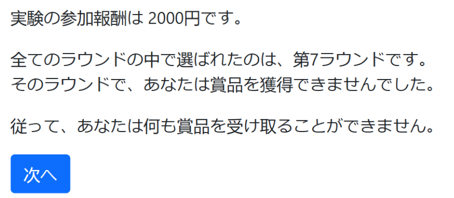


Figure 11: Payment: this page informs the participants of their final payoff.They receive a completion fee for reaching this stage. As shown in this screenshot, the decision that determines the material compensation is round 7, and unfortunately, the participant loses the lottery and therefore receives no eletric appliances.

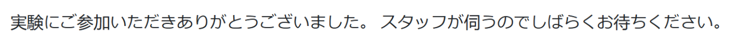


Figure 12: End: The lab staff, monitoring at the front, will approach the participant once he or she reaches the final page.

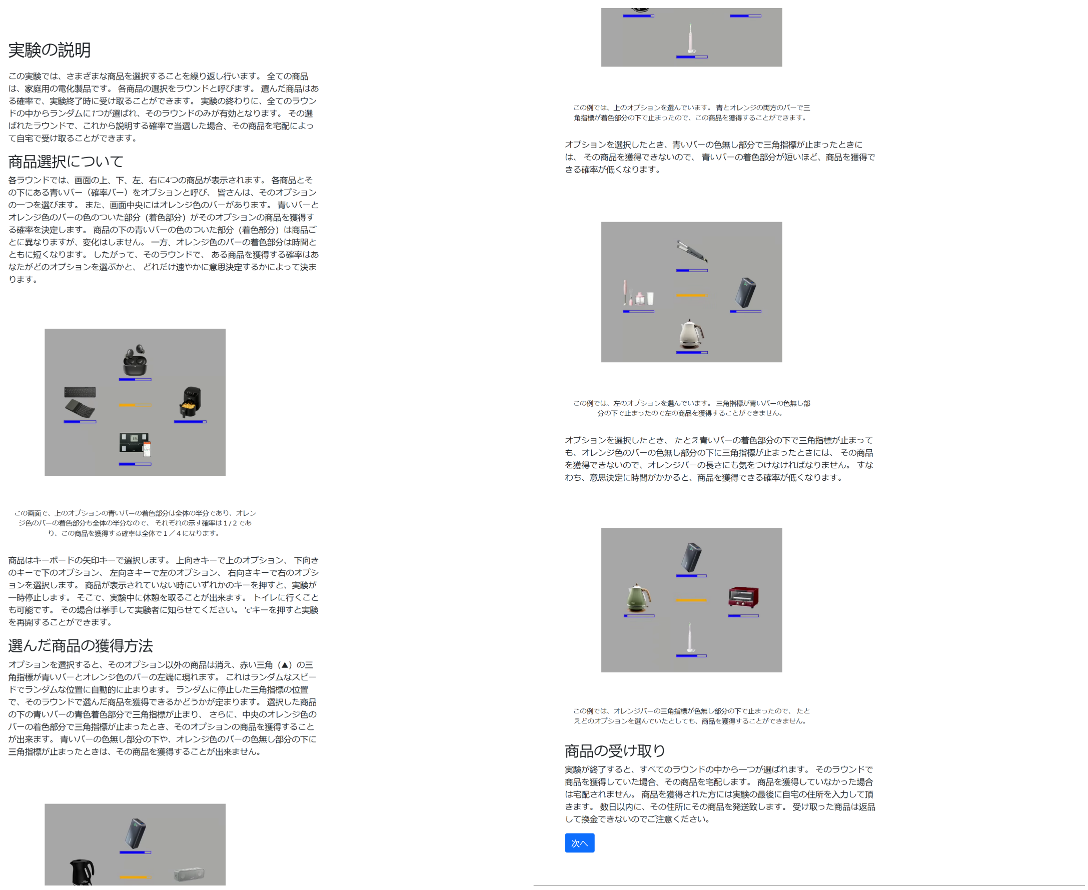


Figure 13: Instructions: This page explains the design of the game and how participants could react to these multi-alternative choice tasks. It also states the decision rules for compensation. For easier comprehension, texts are accompanied with recording snippets. Participants see this page immediately after the welcome page and before a short quiz testing their understanding of the instructions.(The entire webpage is split in half and merged side by side.)

Figure 14: Items: this page provides detailed information of the items to be shown in the experiment, including an image and a short text about its brand and the specific functionalities. (The entire webpage is split in half and merged side by side.)

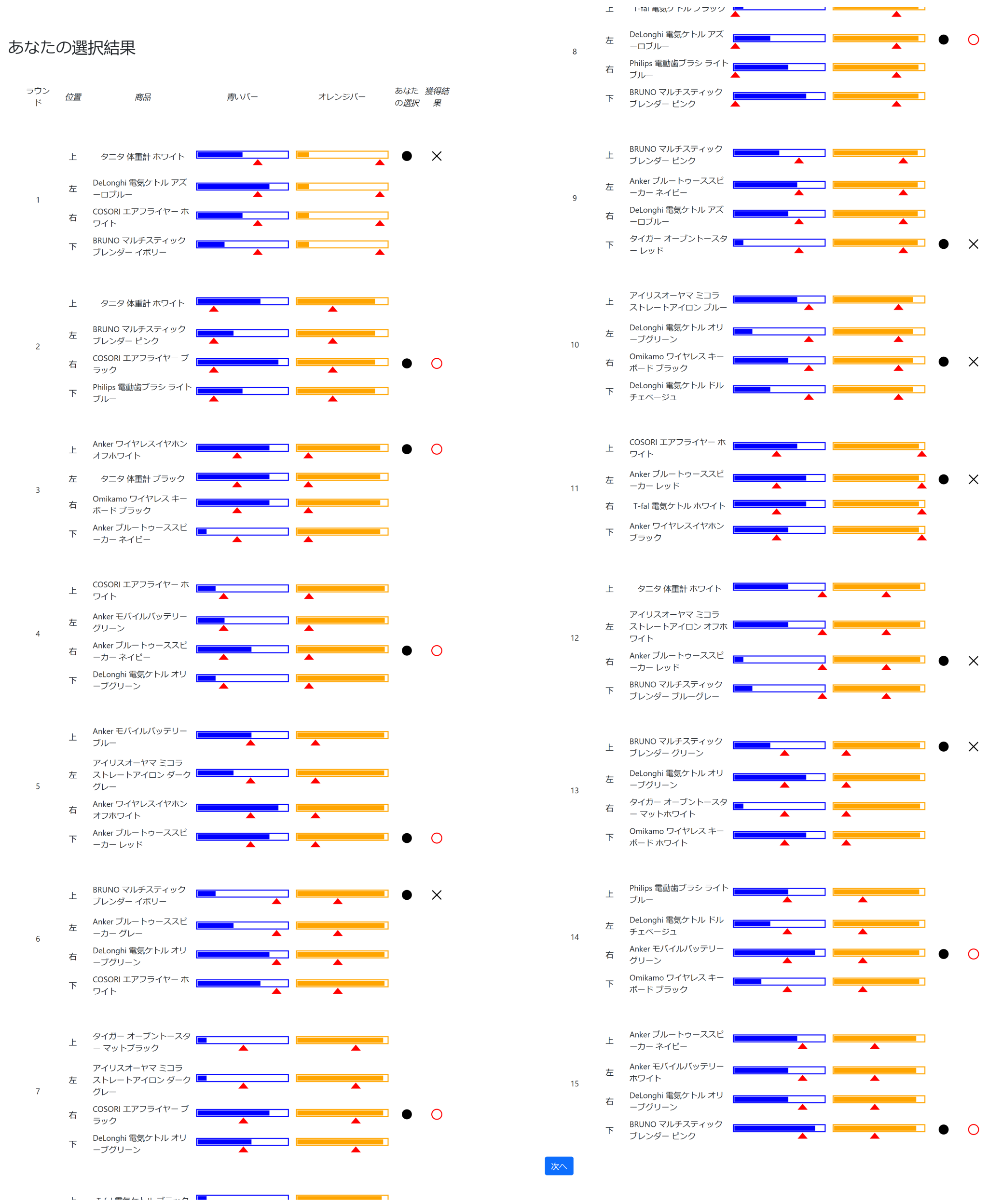


Figure 15: Practice Round Results: this page presents a review of every decision the participant just made. The page redisplays the point where the indicator stops for all items, the participant's selection, and whether they won or lost. (The entire webpage is split in half and merged side by side.)

F Literature Overview Table

Table 7: Summary of Experiments - the DDM and extensions

Paper	Subjects	Samples	Domain	Incentives
Ratcliff and McKoon (2008) Experiment 1	15	10 blocks×96	motion discrimination task (2 directions)	time, accuracy pressure
Ratcliff and McKoon (2008) Experiment 2	14	10 blocks×96	motion discrimination task (2 directions)	time, accuracy pressure separately
Ratcliff and McKoon (2008) Experiment 3	17	10 blocks×96	motion discrimination task (2 directions) with manipulated relative weights assigned to the two possible responses	time, accuracy pressure
Drugowitsch et al. (2012)	6 (human) + 2 (monkey)	562.2 (human average)	motion discrimination task (2 directions)	with and without time pressure
Milosavljevic et al. (2010)	8	2 conditions×750	2AFC (snacks)	no time pressure high time pressure (as quick as possible)
Krajbich and Rangel (2011)	30	NA	3AFC (snacks)	no time pressure
Reutskaja et al. (2011)	41	75	4, 9, 16AFC (snacks)	reaction in 3 seconds failure to react will lead to a 3-dollar penalty if selected as the trial incentivized
Krajbich et al. (2012)	30	300	2AFC (purchase or not) (consumer electronics and household items)	no time pressure
Ashby et al. (2016) Experiment 1	92	18	2, 3, 4AFC (children as donatees)	no time pressure
Ashby et al. (2016) Experiment 2	92	30	2, 4, 8AFC (children, snacks)	no time pressure
Clithero (2018) Experiment 1	31	136	2AFC (snack pairs)	no time pressure
Clithero (2018) Experiment 2	33	153	2AFC (snack bundles)	no time pressure

Table 8: Summary of Experiments - Hick's law

Paper	Subjects	Samples	Details	Incentives
Hyman (1953) Experiment 1	4	approx. 15,000	varying the number of equally probable alternative stimuli	NA
Hyman (1953) Experiment 2	4	approx. 15,000	varying the relative frequency of occurrence of different stimuli	NA
Hyman (1953) Experiment 3	4	approx. 15,000	varying the degree of sequential dependence of stimuli	NA
Brainard et al. (1962)	240	400	factorial design: 4 codes of S-R compatibility test(light/digit×key/vocal response) ×3 levels of stimulus uncertainty× 2 task conditions (self-paced or discrete reaction)	NA
Kornblum (1969)	NA	2 conditions (serial/discrete)×4800	digit/light - key	time, accuracy pressure

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