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ACBC vs. Partial Profile CBC: A Market-Based Comparison

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ACBC vs. Partial Profile CBC: A Market-Based Comparison

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Abstract

Some users of full-profile ACBC have concerns on the length of the questionnaire, especially when there are many attributes and levels. They tend to find the choice questions of Partial-Profile CBC (ppCBC) containing a subset of the full profile to be easier and to fit in better with their thinking logic. Both methods are expected to lead to good prediction results.

In this study, we compared the predictive performances of ACBC against that of partial-profile CBC (ppCBC) in the setting of smartphone choice. We applied the methods with two independent samples of comparable sizes and profiles and followed the recommended designs as well as analysis procedures to examine whether there were significant differences between the two methods.

Our results show that ACBC did take longer to complete than ppCBC on average. The utilities estimated from both ppCBC and ACBC were highly comparable, and the attribute levels' preference ranking from both methods were similar. We also observed that the utilities of ppCBC looked like shrinkage estimators (toward less differentiated attribute importances) of those of ACBC.

However, the predictive accuracy of ACBC is much higher than that of ppCBC with respect to out-of-sample validation and real market sales volume. A smartphone manufacturer adopting ACBC results in its product optimization strategies achieved significantly better market growth than expected and outgrew its benchmark competitor in the new product series.

Background

One of the top three smartphone manufacturers in China came to us for a conjoint research project on how consumers make purchase decisions when facing numerous smartphone features. The research was expected to help the client make better product configurations for both short-term and long-term strategies. More importantly, the client wanted the conjoint research to help them keep the leading position in the fierce competition in the Chinese market.

The long answer time of ACBC was the major concern, although the client highly valued the extra benefits gained from ACBC. As a result, the client wished to adopt a

quick, simple, yet accurate choice experiment. Full-profile CBC was regarded as an alternative, but the client still thought it was too complex for respondents to complete when there were many attributes.

Inspired by the rather simple choice tournament task layout in an ACBC exercise, in which some unchanged attributes are greyed out, the client wanted to know if it was possible to replace ACBC with partial profile CBC. The research conducted by Michael Patterson and Keith Chrzan (Patterson and Chrzan, 2003) showed that ppCBC seems to work well when there were many attributes.

There were some debates between the client and us, but neither side could give convincing evidence to settle on either approach. In order to reach a consistent understanding, the client proposed to run a parallel comparison between ACBC and ppCBC.

RESEARCH DESIGN

We picked one of the client's major product lines for this parallel run experiment. Both ACBC and ppCBC experiments were created by using the same attributes and levels. Moreover, sampling criteria for both studies were the same and the choice data were collected from offline consumers. The final sample sizes for ACBC and ppCBC were 351 and 225.

1. Attributes and Levels

There were 14 attributes in this research. These attributes covered the most important smartphone features, including brand, price, CPU, storage, screen, camera, battery, charging speed, and biometric. The attributes and levels used are in Table 1.

Table 1: Attributes and Levels

Brand (*)	**CPU** (*)	**Rear Camera No.**	**Battery**
Brand H	CPU1	2	3500 mAh
Brand X	CPU2	3	4000 mAh
Brand Y	CPU3		
Brand V	CPU4	**Rear Camera Pixels**	**Fast Charge Speed**
	CPU5	24M	90 mins
Screen Size	CPU6	32M	60 mins
5.80"	CPU7	48M	30 mins
6.40"			
6.65"	**RAM**	**Front Camera No.**	**Biometric**
6.85"	4G	1	Face
	6G	2	Rear fingerprint
Screen Design (*)	8G	3	Screen fingerprint
Design1			
Design2	**ROM**	**Front Camera Pixels**	**Price**
Design3	128G	24M	Summed prices range from
Design4	256G	32M	￥1199 to ￥4999
		40M	

(*) For confidentiality reasons, the real brand names, CPU models, and screen designs are not disclosed here.

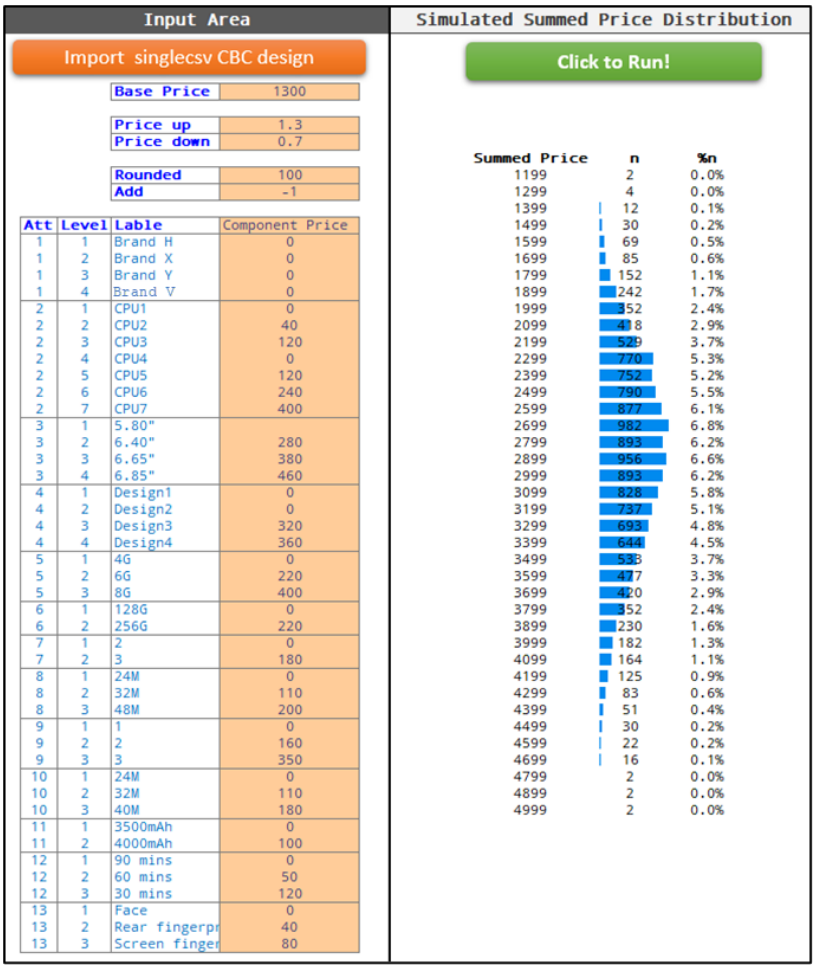
The price attribute in ACBC was designed as summed prices. The price of each concept was summed across the manifested levels of all attributes, and then it was varied with a random draw from anywhere from -30% to +30%. The summed prices were good at giving more reasonable prices than if just randomly drawn from some predefined price levels, even though there were always some difficulties for the client to give precise attribute level component prices.

To address the client's concern surrounding the summed prices, we created a summed price simulator to help the client flexibly adjust component prices and check the summed price distribution at the same time. To do this, a CBC design was created by using the same attributes and levels (not including price) and then the CBC design file was imported to an Excel simulator. The summed prices were calculated, in the Excel simulator, by applying the standard ACBC summed price formula (varying the summed prices +/-30%).

In this way, our client could modify the base price, component prices, and the total price variation range by themselves. And the Excel simulator would automatically simulate the summed prices for each product concept and display the simulated summed price distribution for checking.

This simulation ensured the final summed price distribution was consistent with the real market price distribution even if our guesses for some component prices were not fully accurate. The Excel simulator example is shown in Figure 1.

Figure 1: Summed Price Simulator



Input Area

Import singlecsv CBC design

Base Price	1300
Price up	1.3
Price down	0.7
Rounded	100
Add	-1

Att	Level	Lable	Component Price
1	1	Brand H	0
1	2	Brand X	0
1	3	Brand Y	0
1	4	Brand V	0
2	1	CPU1	0
2	2	CPU2	40
2	3	CPU3	120
2	4	CPU4	0
2	5	CPU5	120
2	6	CPU6	240
2	7	CPU7	400
3	1	5.80"	
3	2	6.40"	280
3	3	6.65"	380
3	4	6.85"	460
4	1	Design1	0
4	2	Design2	0
4	3	Design3	320
4	4	Design4	360
5	1	4G	0
5	2	6G	220
5	3	8G	400
6	1	128G	0
6	2	256G	220
7	1	2	0
7	2	3	180
8	1	24M	0
8	2	32M	110
8	3	48M	200
9	1	1	0
9	2	2	160
9	3	3	350
10	1	24M	0
10	2	32M	110
10	3	40M	180
11	1	3500mAh	0
11	2	4000mAh	100
12	1	90 mins	0
12	2	60 mins	50
12	3	30 mins	120
13	1	Face	0
13	2	Rear fingerpr	40
13	3	Screen finger	80

Simulated Summed Price Distribution

Click to Run!

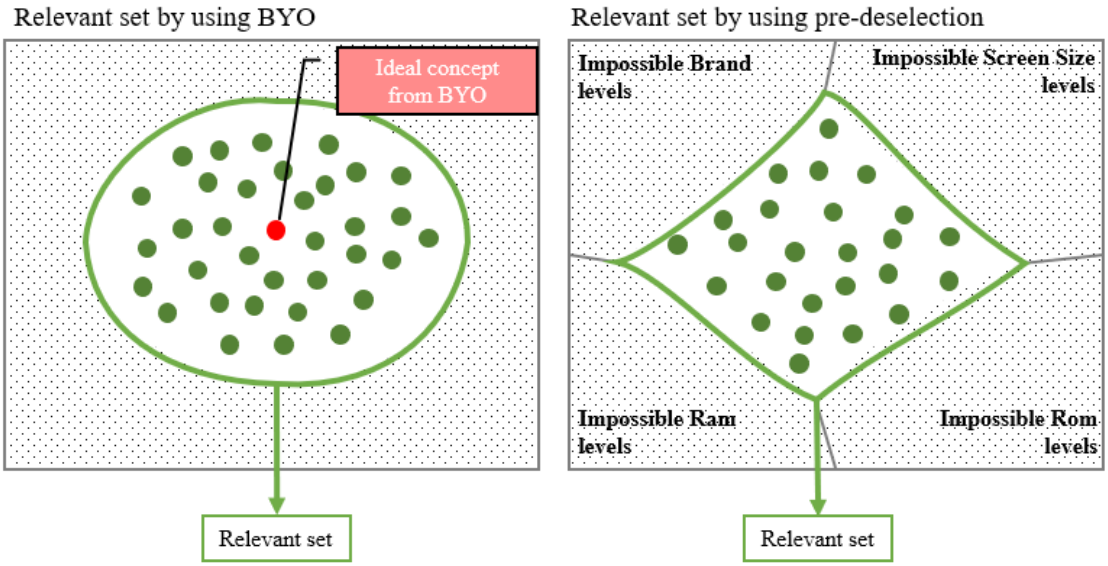
Summed Price	n	%n
1199	2	0.0%
1299	4	0.0%
1399	12	0.1%
1499	30	0.2%
1599	69	0.5%
1699	85	0.6%
1799	152	1.1%
1899	242	1.7%
1999	352	2.4%
2099	418	2.9%
2199	529	3.7%
2299	770	5.3%
2399	752	5.2%
2499	790	5.5%
2599	877	6.1%
2699	982	6.8%
2799	893	6.2%
2899	956	6.6%
2999	893	6.2%
3099	828	5.8%
3199	737	5.1%
3299	693	4.8%
3399	644	4.5%
3499	538	3.7%
3599	477	3.3%
3699	420	2.9%
3799	352	2.4%
3899	230	1.6%
3999	182	1.3%
4099	164	1.1%
4199	125	0.9%
4299	83	0.6%
4399	51	0.4%
4499	30	0.2%
4599	22	0.2%
4699	16	0.1%
4799	2	0.0%
4899	2	0.0%
4999	2	0.0%

2. ACBC Design

In our ACBC exercise, we did not use the standard Build-Your-Own (BYO) question (an option in the software allows you to drop this section). Instead, we asked select-type questions to let the respondent deselect/remove some key attribute levels from consideration, so these levels were not carried forward into the ACBC screening and choice tournament stages.

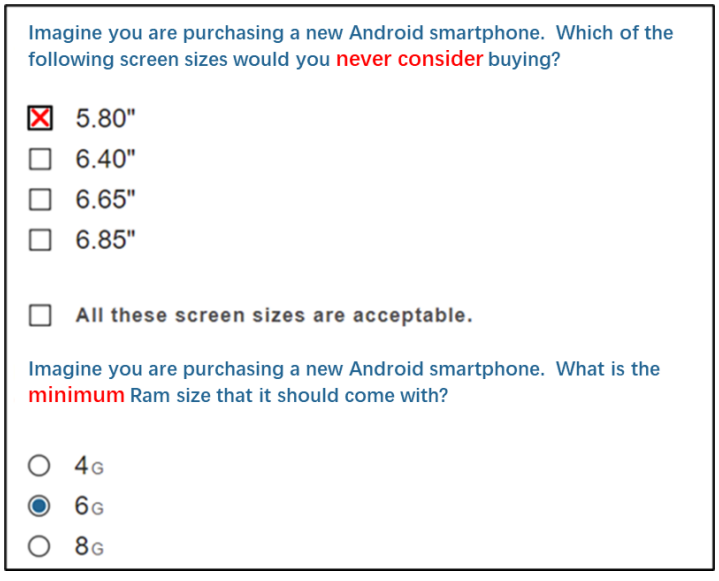
There were two reasons that we removed the BYO question in this study. First, some component prices were confidential, and we did not want to leak this information to respondents in the BYO question. Secondly, the key feature deselection process should be able to help the program home in on the acceptable level ranges even sooner for the key attributes. The differences between the standard BYO and pre-deselection on building relevant product concept set is displayed in Figure 2.

Figure 2: Relevant Set Defined by Standard BYO and Pre-Deselection Question



To avoid removing too many attributes' levels, we allowed respondents to remove levels only from Brand, Screen Size, Ram, and Rom attributes. The deselection question example is in Figure 3. From the client's understanding of the smartphone market, these four attributes were key buying factors for smartphone purchase decisions, and non-compensatory decisions were usually related to these four attributes. After the deselection stage, the desired key attributes' levels were passed into ACBC attribute level lists via Lighthouse Studio's constructed list function. For example, if a respondent deselected 5.80" from the screen size list, then only 6.40", 6.65" and 6.80" would be shown in subsequent ACBC questions. And if this respondent also selected 6G Ram as the minimal requirement, then 4G Ram would not be shown in the subsequent ACBC questions.

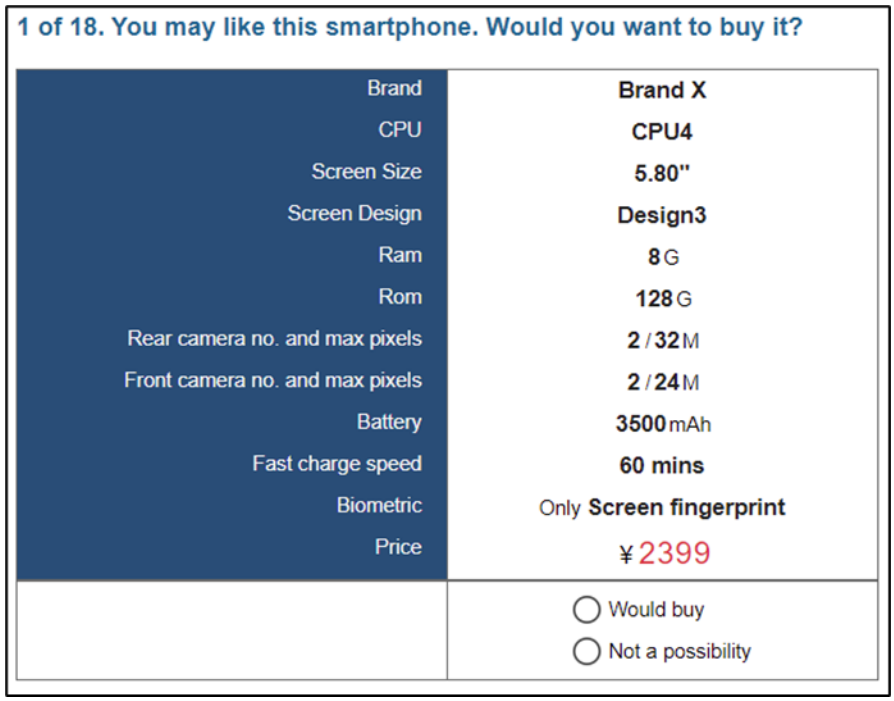
Figure 3: Deselection Question Example



In the ACBC screening stage, we displayed 18 screens of concepts and each screen just had ONE concept. The client hoped consumers would carefully evaluate each concept product for consideration, like what they normally would do in the real world, before making final decisions.

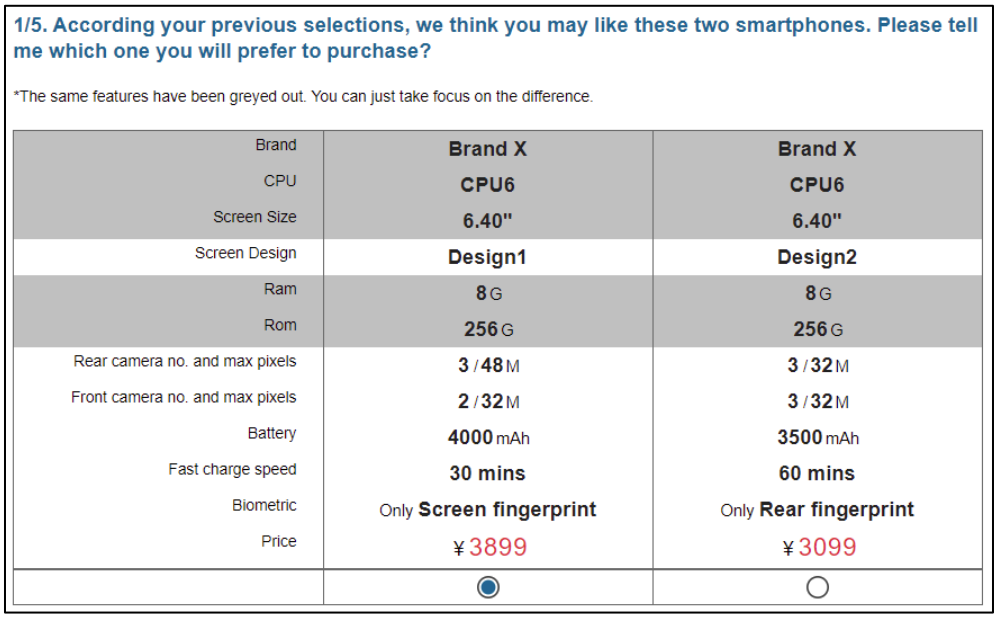
Given the fact it was an offline survey, we believed respondents could complete the 18 screening tasks smoothly. "Unacceptable" and "Must-have" question probes were also allowed in the screening stage, starting from the 10th screening task. A typical screening task in our study is in Figure 4.

Figure 4: Screening Task Example



In the ACBC choice tournament stage, our client preferred showing simpler choice tasks. A recent study by Martin Meissner, Harmen Oppewal, and Joel Huber suggested using pairs of concepts rather than ACBC's default triples when decisions are complex and difficult. We displayed just TWO concept products side by side and asked respondents make a choice in each task. There were 3-12 choice tasks in the choice tournament phase (to narrow down the one winning concept), depending on the number of screened-in concept products for each respondent. The choice task layout is in Figure 5.

Figure 5: Choice Task Example in ACBC Choice Tournament Stage



1/5. According your previous selections, we think you may like these two smartphones. Please tell me which one you will prefer to purchase?

*The same features have been greyed out. You can just take focus on the difference.

Brand	Brand X	Brand X
CPU	CPU6	CPU6
Screen Size	6.40"	6.40"
Screen Design	Design1	Design2
Ram	8G	8G
Rom	256G	256G
Rear camera no. and max pixels	3/48M	3/32M
Front camera no. and max pixels	2/32M	3/32M
Battery	4000mAh	3500mAh
Fast charge speed	30 mins	60 mins
Biometric	Only Screen fingerprint	Only Rear fingerprint
Price	¥3899	¥3099
	◉	○

3. Partial Profile CBC Design

Generally, the partial profile CBC (ppCBC) design had the same attribute and level settings as in ACBC.

In the ppCBC design, 4 out of 14 attributes were varied in each task. The reason we used 4 active attributes in ppCBC came from the study done by Michael Patterson & Keith Chrzan (2003), in which they suggested using 3-5 active attributes in a typical ppCBC. In terms of the number of alternatives per task, we had thought of using paired comparison (two product concepts plus a "none" option), which means we would need to show quite a few tasks to achieve an acceptable design efficiency. Finally, we decided to let each respondent complete 18 tasks with 3 concepts plus a "none" option shown per task.

But we made some changes to the ppCBC exercise. We still showed "full-profile" concepts to respondents. Four attributes were formed from the real ppCBC design while the other attributes were kept at the same levels in each choice task. And we also generated a design for the greyed-out attributes to make sure their levels were varied in a balanced design across tasks.

We used the same summed price calculation for the price attribute to enable the comparability with the ACBC exercise.

We expected the modified ppCBC exercise would share some good characteristics with the full-profile approach (more complete context) while still being simple enough for respondents to complete. To some extent, it looked like the typical choice tournament task in ACBC, where tied attributes were "greyed out." A ppCBC choice task in our study is shown in Figure 6.

Figure 6: Partial Profile CBC Choice Task Example

1 of 18. If you will purchase a brand new Android smartphone, which one of the following product you will buy?

*The same features have been greyed out. You can just take focus on the difference.

Brand	Brand Y	Brand X	Brand H
CPU	CPU3	CPU5	CPU5
Screen Size	6.85"	5.80"	6.65"
Screen Design	Design2	Design2	Design2
Ram	4G	4G	4G
Rom	256G	256G	256G
Rear camero no.	2	2	3
Rear camera max pixels	24M	24M	24M
Front camera no.	3	3	3
Front camera max pixels	32M	32M	32M
Battery	4000mAh	4000mAh	4000mAh
Fast charge speed	90 mins	90 mins	90 mins
Biometric	only Screen fingerprint	only Screen fingerprint	only Screen fingerprint
Price	¥1999	¥1999	¥1999
Please select	○	○	○

○ I wouldn't choose any of these.

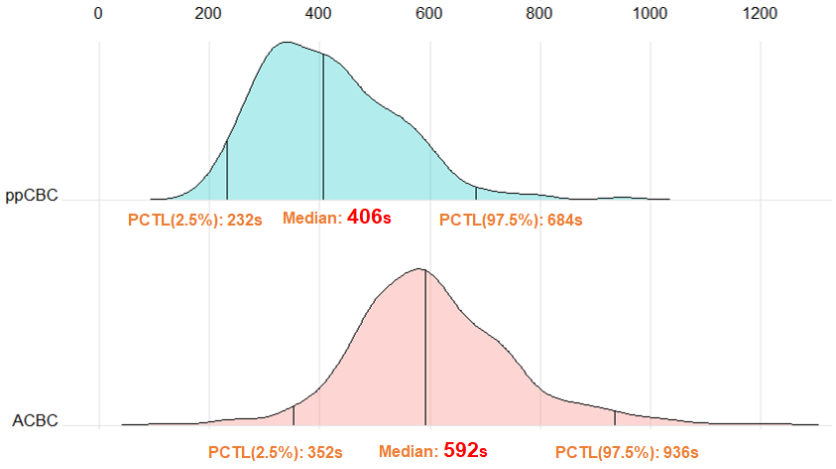
RESULT COMPARISON

1. Answer Time

On average, respondents took 6-7 minutes to complete the partial profile CBC and required about 10 minutes to complete the ACBC exercise. The answer time distribution is in Figure 7.

The actual mean answer time of ACBC was just 1.5 times longer than that of ppCBC, although based on previous research we had expected it would be at least 2-3 times longer than ppCBC.

Figure 7: Answer Time Distribution of ACBC and ppCBC

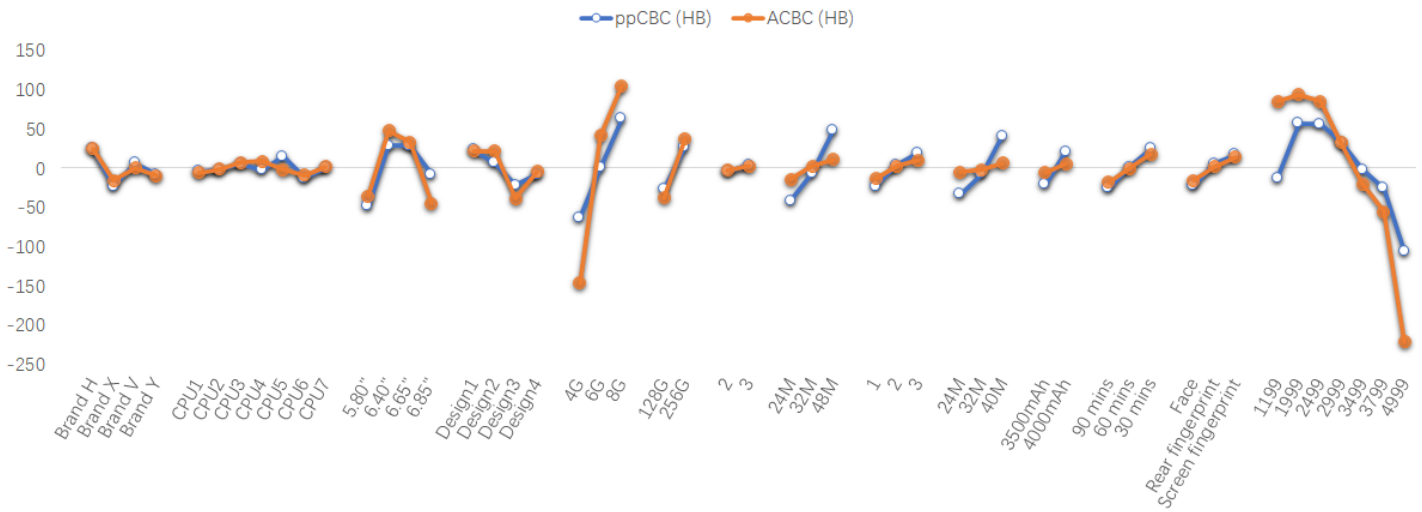


2. Utilities

We used an HB algorithm to estimate the attribute level utilities for both ACBC and partial profile CBC. Prices were piecewise coded when running HB, and seven key price point utilities along the piecewise function were reported for comparison. Both ACBC and ppCBC models used the full-profile coded design matrix.

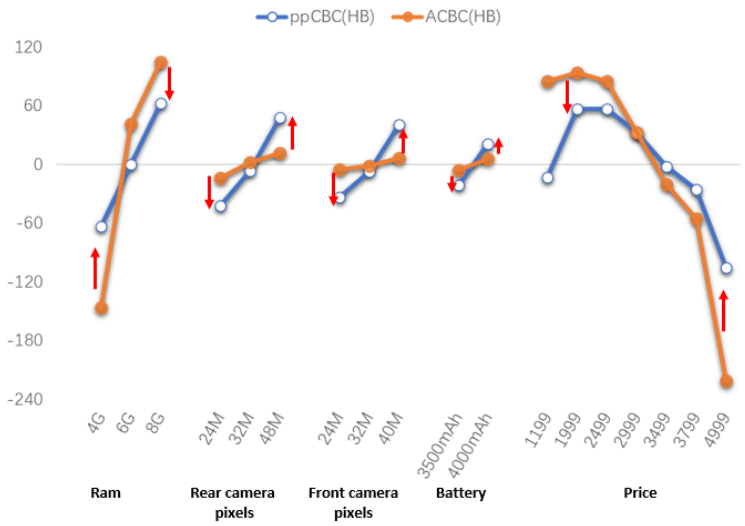
For each attribute, the utility ranking of its levels for ppCBC and ACBC were almost the same. The main-effect utilities per each attribute level are shown in Figure 8.

Figure 8: ACBC and ppCBC Main-Effect Utilities



However, we still observed some inconsistency between these two conjoint exercises. Ram and Price, the top 2 influential attributes in ACBC, became less impactful (relative to the other attributes) in ppCBC. Rear and Front camera pixels, and battery became much more important in ppCBC than in ACBC (again, relative to the other attributes). In general, ppCBC made the attributes' relative importances less extreme than ACBC. This overstatement and understatement of attribute impact is displayed in Figure 9.

Figure 9: Overstatement and Understatement of Impact



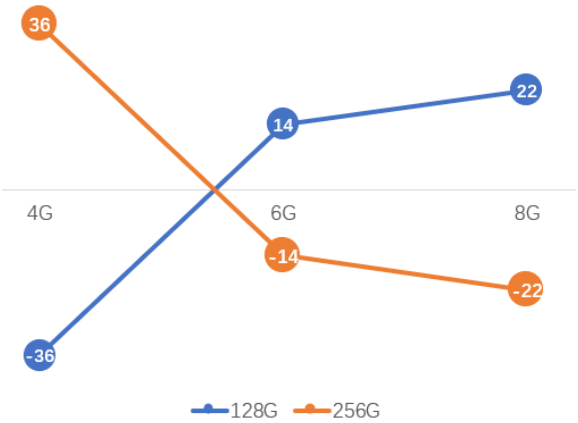
3. Ram and Rom Interaction

We also observed a significant interaction effect between Ram and Rom in ACBC (as modeled as additional parameters beyond the main-effect estimates). In ACBC, as the Ram size increased, the desirability for larger Rom (256G) went down. The interaction effect between Ram and Rom is shown in Figure 10.

It was our client that first asked us to pay attention to the possibility of Ram x Rom interaction effects. From our client's sales experience, they observed many consumers would rather purchase a smartphone equipped with larger Ram than with larger Rom. We tried to add this interaction effect into the model and found it was statistically significant in our ACBC choice data.

We also explored some additional potential interactions proposed by our client, but none of them were found to be as significant as the Ram x Rom interaction.

Figure 10: Ram & Rom Interaction Effect in ACBC



We tried to add a Ram x Rom interaction in the ppCBC model, but the interaction was found very weak in ppCBC. The ppCBC experimental design is less efficient than ACBC's design for detecting and modeling interaction effects. The interaction effects estimation of ACBC and ppCBC are in Table 2.

Table 2: Ram x Rom Interaction Effect in ACBC and ppCBC

	ppCBC (HB)	ACBC (HB)
4G x 128G	8	-36
4G x 256G	-8	36
6G x 128G	-5	14
6G x 256G	5	-14
8G x 128G	-3	22
8G x 256G	3	-22

Out-of-Sample Validation

Our client adopted the conjoint results for her own new product series configuration she intended to launch. Based on ACBC, ppCBC results and other research, they had decided on most of the new product features for the new product line launch, except the Ram & Rom configuration.

At that time, the client focused on scenarios with "8G Ram + 128G Rom" vs. "6G Ram + 256G Rom" competition. These two alternatives had similar prices but might have a cross attribute trade-off involving an interaction effect. Both alternatives were appealing to consumers.

We also tested the client's specific Ram-Rom tradeoff scenario within the ACBC and ppCBC choice simulators to obtain the predicted shares for these two alternatives. The ACBC prediction was based on the model that included the main-effect plus Ram x Rom interaction effect while the ppCBC prediction was purely based on a main-effect model. These two models yielded quite different predictions.

The ppCBC simulation predicted a nearly 50-to-50 share prediction but the ACBC predicted the 8G + 128G alternative (71%) over the 6G + 256G (27%). The prediction result is in Table 3.

Table 3: "8G + 128G" vs. "6G + 256G" Simulation Result

Exercise	Sample Size	6G Ram + 256G Rom	8G Ram + 128G Rom	None
ppCBC	225	49%	46%	5%
ACBC	351	27%	71%	2%

These inconsistent predictions undoubtedly instigated some internal debates on the client side. Some people thought the ACBC prediction was right while others trusted the ppCBC prediction.

To justify which conjoint method was better for predicting the specific Ram-Rom tradeoff of interest, the client invested in a follow-up out-of-sample validation study. Three new groups of respondents were simply asked to make a choice isolating the

tradeoff between the two attributes among "8G + 128G," "6G +256G," and "None" alternatives. The validation study was independently executed by a third party.

- Group1: online consumers (n=609)
- Group2: offline consumers (n=453)
- Group3: the client's offline-channel shop assistants (n=316)

The "8G + 128G" choice ratios for the 3 validation groups were 70%, 75%, and 76%, which were extremely close to the ACBC predictions (71%). The validation result is shown in Table 4.

Table 4: Out-of-Sample Choice Ratio Per Each Validation Group

Validation group	Sample Size	6G Ram + 256G Rom	8G Ram + 128G Rom	None
Online consumers	609	22%	70%	8%
Offline consumers	453	24%	75%	1%
Shop assistants	316	14%	76%	10%

This validation result gave our client more confidence to downsize or eliminate the 6G + 256G configuration in the new product line series.

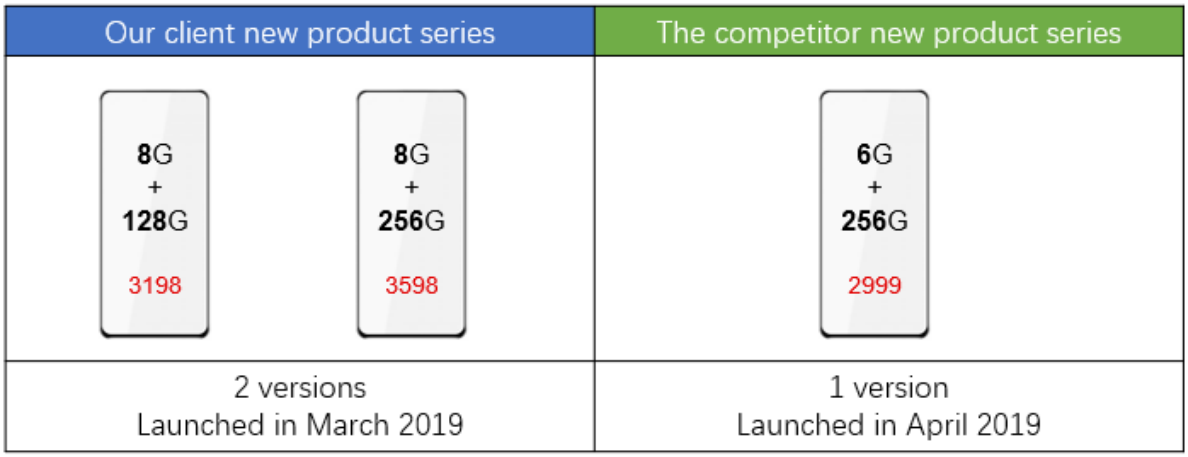
We think the following reasons helped ACBC make a more accurate prediction of the isolated Ram-Rom tradeoffs. First, ACBC is much more relevant and efficient than a ppCBC design. The adaptive mechanism, although a little bit tedious, really worked to hit the consideration space for most respondents. Secondly, ACBC's more efficient experimental design (with respect to interaction effects) was able to detect the unwillingness to upgrade Rom when Ram was good enough (the Ram x Rom interaction effect).

Real Market Competition

We also had an opportunity to verify the ACBC prediction results in real market competition. The conjoint studies we've described to this point were executed in November of 2018 and the client's new product series was launched 4 months later.

Our client's new product line had two versions: 8G Ram + 128G Rom and 8G Ram + 256G Rom. The major competitor's new product series just had one version: 6G Ram + 256G Rom. Both the client's new product series and the competitor's new product series were launched in adjacent months in 2019. See Figure 11 for the competition details.

Figure 11: Real Market Competition



Both product series shared a lot of features except Ram, Rom, and price. These two brands had quite similar brand image and were positioned similarly in the market. Their offline channel coverage and sales capability were largely comparable, and their offline stores were almost side by side on the same street. Additionally, their production capacities were highly comparable. In short, the external effects for these two brands' competition can be somewhat ignored.

We also conducted a market simulation based on ACBC utilities. In this simulation, we applied the product availability factor (multi-store adjustment) to mimic the real market situation. Given the same production capacity, a multi-product strategy may result in more "out of stock" opportunity than single-product strategy, especially when the major sales of our client came from offline channels.

After checking the real historical sales data, our client confirmed ACBC's simulated relative preference share was remarkably close to the real market sales ratio. Our client praised ACBC highly for its market simulation predictive power. Although the client's new product was priced even higher than the competitor's product, they in the end achieved 16 percent more revenue than the competitor's product. The relative predicted shares from the ACBC simulator and the observed real market shares are in Figure 12.

Figure 12: Relative Simulated Share and Real Market Share

	The client's new product series		Competitor product series
Ram & Rom	8G + 128G	8G + 256G	6G + 256G
Price	3198	3598	2999
Launch date	March 2019	March 2019	April 2019
Simulated Share (relative)	33.3%	20.7%	46.0%
Real Share (relative)	30.6%	20.3%	49.1%

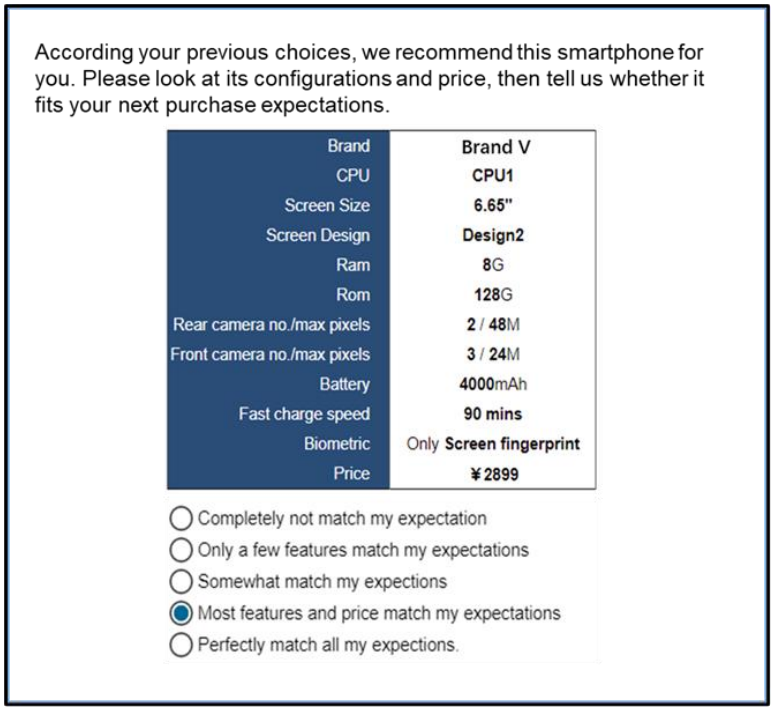
To conclude, the out-of-sample validation question (that isolated the Ram-Rom tradeoff) may only serve to verify a single aspect of the competition. In contrast, ACBC

involving all 14 attributes empowered the client to incorporate the full picture of the features and competition and allowed us to answer many more "what-if" scenario questions.

ACBC Deep Dive

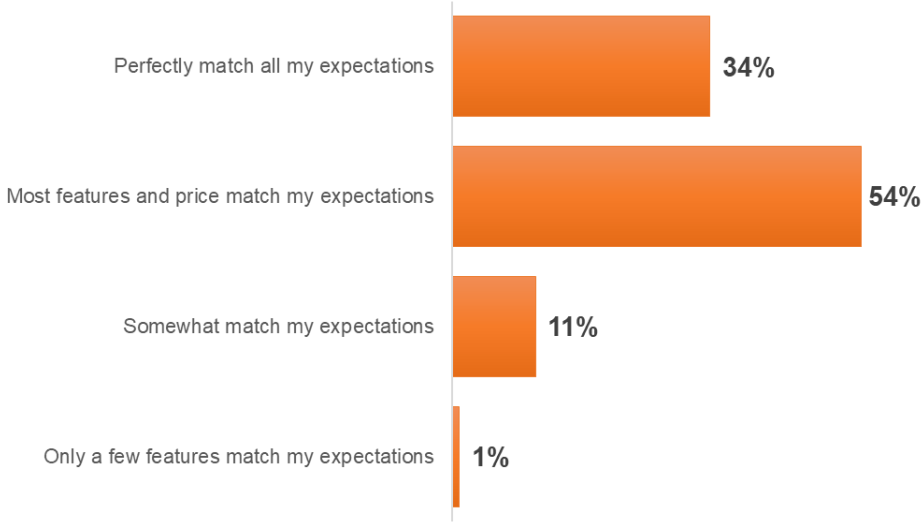
When we reviewed this study, we also did some exploration of the ACBC data. Actually, at the end of the ACBC questionnaire section, we took the ACBC winning concept and asked each respondent to evaluate the winning concept's fitness against their own expectations. This fitness assessment question example is in Figure 13.

Figure 13: Fitness Assessment for the ACBC Winning Concept



The claimed fitness was exceedingly high. Nearly 90% of respondents thought the ACBC winning product fit their expectations very well. See Figure 14.

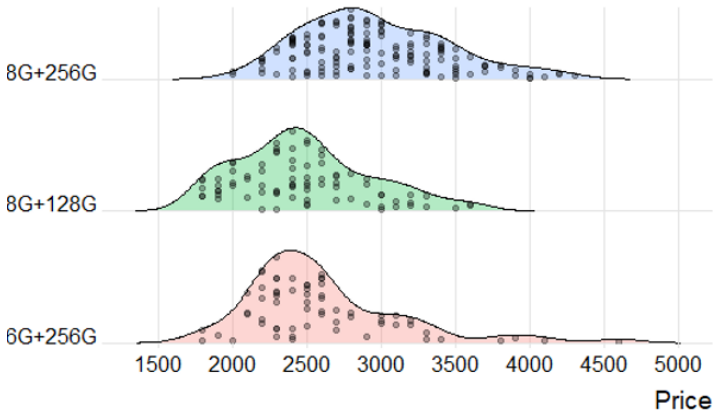
Figure 14: Claimed Fitness of ACBC Winning Concept



This result also showed that the dynamic ACBC process could help to identify the optimal or near optimal concepts at the individual level, even without modeling the choice data.

The winning concepts' median price by different Ram & Rom combination also make sense from the client's perspective. See Figure 15.

Figure 15: ACBC Winning Concept's Price Distribution

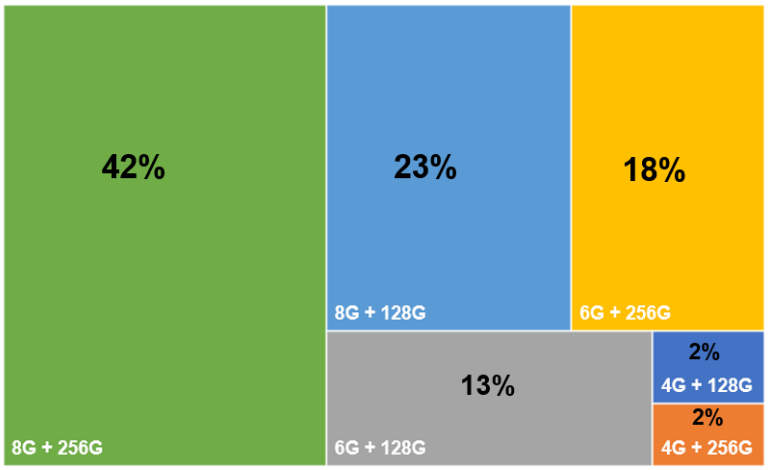


Winning products' price percentile

	2.5%	50.0%	97.5%
6G + 256G	1854	2499	3989
8G + 128G	1799	2399	3502
8G + 256G	2199	2899	4029

We also reviewed the Ram and Rom configuration count among all winning products. “8G + 256G” and “8G +128G” products were the top 2 winners, followed by “6G + 256G” product. See Figure 16.

Figure 16: Ram and Rom Count of ACBC Winning Concept



And we compared the Ram x Rom counts result from ACBC winning products with the Ram x Rom counts result from the pre-deselection questions. The result is shown in Table 5.

Table 5: Ram x Rom size of ACBC Winning Products by Self-Claimed Acceptable Ram x Rom

Pre-deselection kept in levels	ACBC winning concepts					
	4G+128G	4G+256G	6G+128G	6G+256G	8G+128G	8G+256G
4G+128G	18.2%	15.9%	15.9%	11.4%	**22.7%**	15.9%
4G+256G	17.8%	15.6%	15.6%	11.1%	**22.2%**	17.8%
6G+128G	3.7%	3.2%	20.1%	**26.0%**	**25.1%**	21.9%
6G+256G	3.4%	2.9%	18.5%	**26.5%**	**23.1%**	**25.6%**
8G+128G	2.9%	2.5%	15.8%	20.4%	**28.7%**	**29.7%**
8G+256G	2.3%	2.0%	12.5%	17.9%	**22.8%**	**42.5%**

This table also shows some inclination to upgrade Ram to 8G rather than to 6G. Those who accepted low Ram size (4G) or high Ram size (8G) would like to choose an 8G Ram product as the best one. Those who accepted medium Ram size (6G) would largely choose a 6G Ram as the best one but they also like 8G Ram products very much.

CONCLUSIONS

In this study, ppCBC was proved to be less accurate in prediction than ACBC when there were many (14) attributes. ppCBC overestimated the impact of some negligible attributes while underestimating some important attributes. An important interaction

between Ram and Rom could not be detected either at the aggregate level or individual level in ppCBC.

A tailored key attributes level deselection process can replace the standard BYO under some circumstances and help the ACBC program quickly approach a more meaningful solution space for each respondent. But researchers should be cautious to include these key attributes in the design to avoid eliminating some meaningful attribute levels at the very beginning. The dynamic mechanism in ACBC and its resulting experimental design was helpful in identifying meaningful interactions between attributes.

ACBC worked much better than ppCBC in out-of-sample validation, as well as in market simulation. In a perfectly competitive market, where the external effects were held at the same level for different brands, as shown in this study, the ACBC model can accurately predict the real market share.

Considerations for Future Research

In this comparison study, the ppCBC just had 4 out of 14 attributes varied in the design. When we reviewed this study, we thought the ratio (4/14) was too low to get enough information to detect interactions. And the fewer the active attributes, the more likely respondents are to overrate some negligible factors.

Some previous studies (e.g., Keith Chrzan and Michael Patterson's presentation in the 2003 Sawtooth Software conference) have explored the optimal number of attributes shown in ppCBC (main effect model); still some experiments are needed to explore the optimal number of attributes shown in ppCBC when there are non-compensatory behaviors or interactions. We thought the constructed attribute list CBC, which let respondents first choose several most influential attributes and then just show these considered attributes in conjoint task, would also be worth trying to improve the efficiency and relevancy of the ppCBC design.

And we will also need to examine the held-constant attribute contribution in our ppCBC compared to the zeroing out the held-constant levels in the design matrix. In our study, we shaped the ppCBC choice task as a full-profile one with "none" option included. Without a "none" concept, the held constant (greyed out) levels across attributes do not contribute any information to utility estimation, although they provide more context for the respondent as the respondent answers the choice tasks. But, with a "none" concept in the choice task, the held-constant attributes indeed DO contribute some information to the design and for utility estimation. But we still need some empirical studies to know how much this method can improve the design efficiency or prediction power of ppCBC.

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