HIP Analysis of Breville Barista Express

ISEN 635 - Human Information Processing

Fall 2020

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I. EXECUTIVE SUMMARY

These days, it seems like every hobby, no matter how niche, has a market and this holds especially true for avid coffee drinkers. With a machine available to fit anybody's coffee preferences, Breville has made a name for itself for not only making high quality drip coffee makers, but espresso machines as well. This project will analyze the Breville Barista Express, the entry level espresso machine for espresso aficionados. Specifically, we will try to understand how the machine initiates dose control of coffee grounds, the metrics it uses for optimal espresso extraction, and the usability of the micro foam creating steam wand. After each of these components has been explored individually, we will explore how well this machine works in conveying all of this information to a user so they are confident in their ability to create an espresso drink that Breville claims to have that "authentic cafe style." Within this process we will also delve into some of the issues this machine has and propose some improvements. The current study will conclude with an espresso tasting to determine user sensitivity to the machine's signals as it guides the user through the espresso making process.

To quantify the above-mentioned "authentic-cafe" experience, the subjective definitions of "good espresso" and "bad espresso" will be established for the scope of the paper. Signal Detection Theory (SDT) will then be used to determine the sensitivity (d') of the espresso machine. To understand user-variability, two participants will make ten shots of espresso each and classify them as hits, misses, false alarms, and correct rejections based on the signals that the machine sends out. To clarify further, the study will not be assessing the machine's sensitivity but rather the machine's ability to help the user interpret the machine's signal/noise. Each of the four terms (hits, misses, correct rejections, false alarms) have been defined in the context of the Signal Detection Theory. Additionally, further analysis on the espresso machine's user-interface and usability is performed in terms of attention and visual processing of information from the machine. The machine, overall, is easy to use and intuitive in how it operates. In the spirit of making signal detection more robust, two improvements are suggested aimed at increasing the usability of this espresso machine.

Furthermore, the authors recognize the plethora of influencing factors of the taste of espresso, in terms of goodness or badness of the shot. To ground the study as much as possible and reduce the user variability, two participants were made to conduct the experiment ten times each to collect data. While the user with more experience did have a higher sensitivity compared to the other user, the overall sensitivity for both users was very high indicating that the machine is effective in sending out the correct signals so the user's espresso making process is as seamless as possible.

II. INTRODUCTION AND DESIGN DESCRIPTION

The Breville Barista Express is an automatic espresso machine, which means the machine comes preprogrammed to regulate how much water is dispensed for each espresso shot. As shown in the Top image of Figure 1, this machine has three main user interface sections, and these are organized to be used starting from the top left side (Espresso Prep), through the center (Espresso Extraction), and ends on the far bottom-right side (Steam). This layout is congruent with the established espresso drink making process and adds a layer of intuitiveness for the user. Before beginning, the user must ensure the water tank (located at the back of the machine) has enough cold filtered water. Once the machine is plugged in and turned on using the Power button on the far right side of the control panel. The machine will make a loud grinding noise, indicating the initiation of the initial heating process. While the machine is heating, the white ring of light (the surround) around the Power button will flash. Once the correct internal temperature is reached, all of the control panel button surrounds will illuminate (Figure 1, Bottom), indicating the machine is ready for use. Please refer to Figure 9 in the appendix for a detailed breakdown of the machine's components. Over the next few sections, we will take a closer look at how each component of the Breville Barista Express functions to help the user make a "good" espresso drink.

Figure 1: (Top) *Breville Espresso Machine divided by function and (Bottom) the illuminated control panel*

Espresso Preparation: User starts the espresso preparation (prep.) by inserting the desired amount of roasted whole espresso beans into the clear canister at the top right corner of the machine. They will set the grind size and volume to the values provided by the roaster (usually located on the side of the whole-bean packaging), and will ensure the filter size is set to either “Single” or “Double” (depending on whether they want a single or double shot of espresso) . The user will use the portafilter (Figure 9, V) to activate grinding in the grinding cradle (Figure 9, G) and the basket within the portafilter will fill with freshly ground coffee beans. Once the desired volume has been reached, the user will pull the portafilter from the grinding cradle, tamp the ground within the portafilter using the tamper (Figure 9, F), and twist-insert it into the group head (Figure 9, K) .

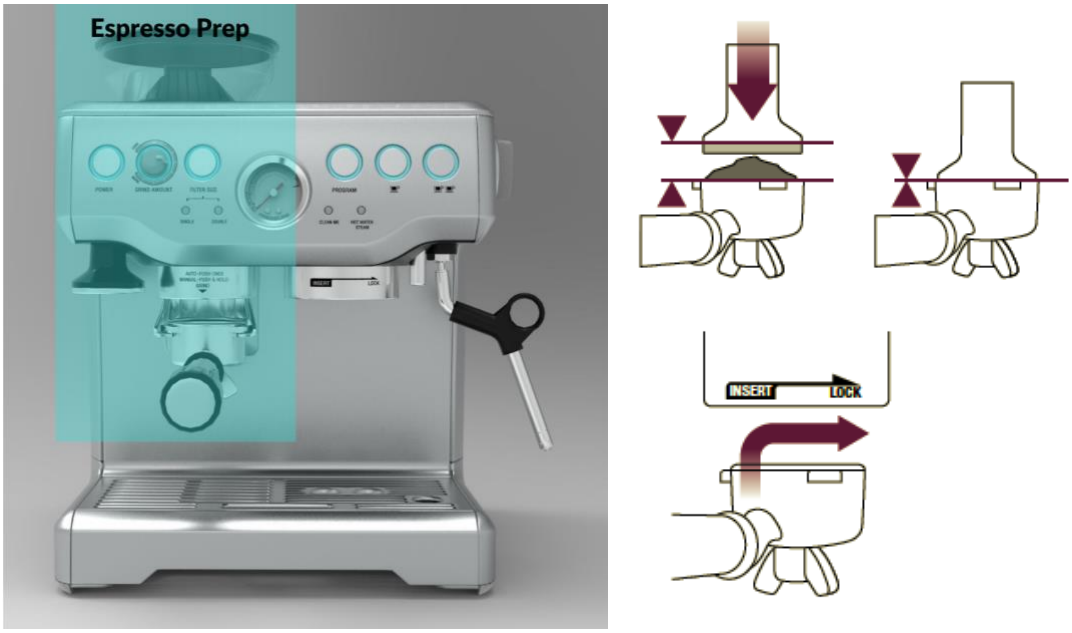


Figure 2: (Left) *Highlighted section encompass components of Espresso Preparation. (Top Right) Tamping process for fresh ground coffee beans. (Bottom Right) The portafilter’s insert mechanism into the group head.*

Espresso Extraction: Within this section, the user will begin the process of extracting espresso in which the machine pushed a predetermined amount of hot water through the grounds in the portafilter (Figure 3 (Left)). User will place the preferred drinking receptacle under the portafilter (to catch the extracted espresso) and press either the 1 cup (Figure 3 (Top Right)) or 2 cup bottom (Figure 3 (Bottom Right)). This selection corresponds with the amount of ground dispensed in the previous step as the volume of water used will depend on if the user desired a single shot (30mL of water) or a double shot (60mL of water). Once the desired button has been pressed, the button surrounding will start flashing and the machine will again start to make a loud pumping noise, indicating extraction is about to begin. Espresso will begin to flow from within 4 to 8 seconds and the user must watch the gauge (located at the center of the control panel) to

determine if their espresso extraction will fall within the ideal/desired range which will give an indication of the espresso quality.

Figure 3: *(Left) Highlighted section encompasses components in Espresso Extraction. (Top Right) Single shot extraction vs (Bottom) Double shot extraction*

Steam: After the espresso shot has been extracted (a shot has been "pulled") and the user is content with the quality of the extraction, they can now move into the final section of the machine (Figure 4, Left). From here the user has three options: 1) stop here and enjoy just the espresso, 2) turn the steam/hot water (s/hw) dial (Figure 9, S & Figure 4, Top Right) clockwise to enable the hot-water function (for an Americano) or 3) turn the s/hw dial counter-clockwise to enable the steam wand function. If option 2 is chosen, the user simply needs to place their drinking receptacle under the water spout (Figure 9, U), turn the (s/hw) dial to the hot water function and turn the dial back to the neutral position once the desired volume of water has been dispensed. If option 3 is chosen, the user must purge the steam wand before utilizing it to texture milk. This is done by pushing the steam want into the machine so the steam wand tip is positioned over the drip tray (Figure 9, M), and turning the s/hw dial counterclockwise from standby into the steam position. The machine will again make a loud thumping noise and steam will slowly flow from the steam wand tip. User will wait until steam flows steadily and robustly, and then turn the s/hw dial back to the standby position (Figure 9, Top Right), pausing the flow of the steam. The steam wand is then quickly inserted into a pitcher with cold milk where the tip is angled and submerged just underneath the milk's surface. The angled steam coming from the wand tip will push the milk to spin in a clockwise direction (Figure 4, Bottom Right)and the user can texture their milk to accommodate their preference.

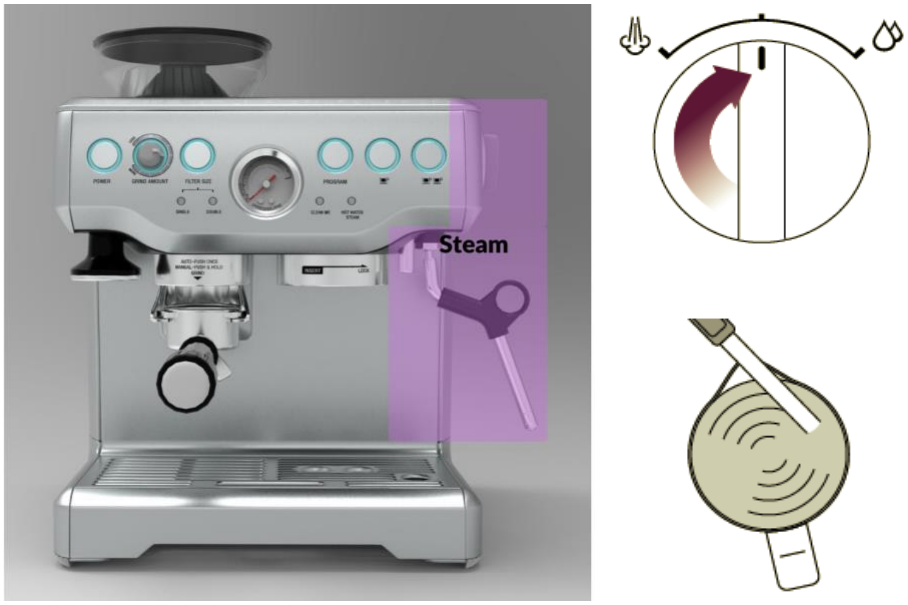


Figure 4: *(Left) Highlighted segments encompass the steam functions. (Top Right) S/HW dial moving from Step to Standby position (Bottom Right) Milk spinning as it is steamed by the steam want*

III. ANALYSIS METHODS

Signal Detection Theory

To understand the espresso machine's ability to inform the user if they are about to pull a 'good' vs. 'bad' shot, Signal Detection Theory was used to calculate the sensitivity of the machine. In other words, how the espresso machine works to help the user know when they have correctly pulled a good versus a bad shot. Refer to Table 1 for the definitions of hit, miss, correct rejection and false alarm. The Pressure gauge (at the center of the control panel) has split up the range into three segments: Ideal Espresso, Under-extracted, and Over-extracted (Figure 5). As espresso flavor can be very subjective, the ideal espresso range is large compared to the other two to accommodate this. The user simply needs to see where the needle falls as the shot is being pulled to know if they should keep the shot (Hit) or throw it out and start over (Correct Rejection).

In addition to the pressure gauge, the machine itself makes a sound as the water is being pushed through the portafilter. If the sound is really high pitched, then the machine is working really hard and requires a lot of pressure to push the water though and the espresso will likely be over extracted. If the sound is low, water has rushed through the espresso grounds without much resistance and the shot may be under-extracted. In having both of these signals, the machine really aims to ensure the user does not fall into the Miss or False Alarm range and spends most of their time in the Hit and Correct Rejection ranges.

Assumptions: It should be noted that we assume the User of the Breville Barista Express have some experience with the espresso making process and have a general familiarity with espresso machine functionality. As this machine is currently priced at almost $700, it is not something one easily invests in with minimal experience (1). Whether a shot will be a 'good' or 'bad' can be influenced by the freshness of coffee beans, ground bean grains, how tightly ground beans are packed, the type of water used, etc.To cut down on variances from external factors, the same type of coffee beans and filtered water were used. Additionally, two shots of espresso were extracted with each run and only 2% milk was steamed.

	Signal	**Noise**
Yes	**Hit** Keeping espresso shot with pressure is in ideal espresso zone	**False Alarm** Dump out espresso even when it is within ideal pressure zone
No	**Miss** Keeping espresso shot with pressure not in "ideal" espresso zone	**Correct Rejection** Dump out espresso because pressure outside ideal pressure zone

Table 1*: Signal Detection Theory*

Under-Extracted Zone 'Ideal' Espresso Zone Over-Extracted Zone

Figure 5: *Three possible zones for Espresso Extraction*

Attention in Visual Processing

As good espresso requires both attention and precision, this machine recruits the concepts of attention in visual procession. With attention, there is the Bottom-up attention orientation in which the machine creates redundancy by utilizing both auditory and visual processing in the user to really make sure the user is paying attention. By targeting both of these processing pathways, the machine targets the user's tendency for selective attention while also ensuring the user's visual channels are not overloaded. At each step of the process, the machine uses auditory cues to notify the user of the current status. For example, when the

machine is first turned on, a loud grinding sound is heard followed by some pumps. This indicated the machine has initiated the heating of itself and the water reservoir. Once the machine has finished heating up, the machine ceases making that sound indicating to the user the machine is ready for use.

This machine is also designed for Visual Processing with its top-down attention orientation. The three main components are all set-up to flow from the top left corner of the machine to the bottom right, following the general flow that's congruent with the natural scanning tendencies in humans (in most cultures) of working left-to-right and top-to-bottom. As shown clearly in Figure 1, the buttons on the machine light up, making them salient features of the machine making it easy to operate. The buttons lightening up when they are being used, and reinforcing for the user what part of the espresso making process they are in also provides another layer of salience.

IV. PROBLEMS

Although the Breville Barista Express is a very refined machine, there are many improvements that can be made to make this machine safer and more efficient to use. The first problem would be adding an indicator to the machine indicating water level or moving the location of the water tank on the machine. The water tank is essential to the functionality of the espresso machine as water is necessary to heat up the espresso machine. If there is not enough water in the machine when the espresso is being made, the machine can malfunction or even break. There are also other improvements that can be made to make the machine more efficient and worthy of it's overall price such as adding an additional boiler and steam wand.

V. REDESIGN SOLUTIONS

Practical Redesign - Water Level LED and Increased Water Reservoir Size

Through some analysis, a simple solution to this issue would be to add little LED light indicators. One of the LED indicators would light up yellow, and this would warn the user that the water reservoir is getting low and will need to be refilled very soon. The other LED indicator would light up red, and this would alert the user that the water reservoir is below the recommended levels and needs to be refilled immediately. The outer side of the water reservoir currently has a "Min" level marking, when water reaches this level the machine can be triggered to illuminate the yellow light. When the water levels are 6mL below that, the machine can be triggered to illuminate the red light. Having yellow and red as the two colors add salience to the message that's trying to be conveyed by the machine, with yellow being the cautionary signal and red being the altet signal.

Figure 6: *Adding LED's for water level signal*

As shown in Figure 6, these two LED indicators would be situated right under the power button (ie the far left side of the control panel). This location takes advantage of one's visual processing tendencies of scanning from left-to-right. This location also increases the chances of the user seeing them (if they are illuminated) before they have begun the espresso making process and taking the correct steps to ensure the continued health and quality of the machine.

Figure 7: *Increasing the size of Water Reservoir*

Increasing the size of the water reservoir in addition to adding the two LED lights will also increase the chances of a Hit since the likelihood of water level being low will decrease.

High In The Sky Redesign - Additional Boiler and Steam Wand

Adding an additional boiler would be beneficial to the machine as it would increase the speed at which the machine heats up. The boiler would also increase the steam output of the steam want and also ensure more uniformity in temperature distribution for the steam wand. This improvement in the steam wand's

functionality would ensure the purges fully clean out the interior lining of the steam want while also delivering more steam consistency when the wand is being used to texture milk. Having a higher powered steam wand would also allow the user to explore more milk options. While whole milk and 2% milk have enough fat content to work well with most kinds of steam wands, alternative milks can be trickier to get right without enough steam power.

Adding an additional steam wand would allow for two latte drinks to potentially be made at the same time, thereby increasing the productivity level of the machine and effectively decreasing the user's selective attention tendencies. This will also keep the user engaged and prevents any signals being missed due to any lack of attention.

VI. RESULTS

Signal Detection Theory

The effectiveness of the Breville Espresso machine will be evaluated by using Signal Detection Theory. In Table 1 below the values of Hit, Miss, False Alarm and Correct Rejection have been defined.

	Signal	**Noise**
Yes	**Hit** Keeping espresso shot with pressure is in ideal espresso zone	**False Alarm** Dump out espresso even when it is within ideal pressure zone
No	**Miss** Keeping espresso shot with pressure not in “ideal” espresso zone	**Correct Rejection** Dump out espresso because pressure outside ideal pressure zone

Table 1 (shown again)*: Signal Detection Theory*

Sensitivity Comparison

Next, a comparative analysis was conducted between two participants, Participant A and Participant B to see who had better sensitivity in differentiating good express vs. bad espresso. This will help determine if the machine is truly effective at showing the user the difference between good vs. bad espresso despite the user's experience level as long as they had some knowledge of how to use an espresso machine prior. A total of 20 espresso shots were made with each member responsible for 10 of the 20 espresso shots. The number of Hits, Misses, False Alarms, and Correct Rejections were accounted for and the probabilities of

each was determined so sensitivity could be calculated. The following equations were used as a basis for further calculations:

$$P(H) + P(M) = 1$$
$$P(FA) + P(CR) = 1$$

Participant A (out of 10)	**Participant B (out of 10)**
Number of Hits (H) = 7 Number of Miss (M) = 1 Number of Correct Rejection (CR) = 1 Number of False Alarm (FA) = 1	Number of Hits (H) = 6 Number of Miss (M) = 1 Number of Correct Rejections (CR) = 2 Number of False Alarms (FA) = 1
Probability of Hit $P(H) = \frac{7}{10} = 0.7$	Probability of Hit $P(H) = \frac{6}{10} = 0.6$
Probability of False Alarm $P(FA) = \frac{1}{10} = 0.1$	Probability of False Alarm $P(FA) = \frac{1}{10} = 0.1$
Probability of Miss $P(M) = \frac{1}{10} = 0.1$	Probability of Miss $P(M) = \frac{1}{10} = 0.1$
Probability of Correct Rejection $P(CR) = \frac{1}{10} = 0.1$	Probability of Correct Rejection $P(CR) = \frac{2}{10} = 0.2$

Table 2: *Relevant Probabilities of SDT*

After calculating the probabilities, the NORMSINV function is then used in Microsoft Excel to calculate the Z values for Hits and False Alarm, which will then be used to calculate the sensitivity for each individual's machine usage.

$Z(P(FA))$ = NORMSINV(0.1) = -1.28	$Z(P(FA))$ = NORMSINV(0.1) = -1.28
$Z(P(H))$ = NORMSINV(0.7) = 0.52	$Z(P(H))$ = NORMSINV(0.6) = 0.25
Participant A's Sensitivity $d' = \lvert Z(P(H)) \rvert + \lvert Z(P(FA)) \rvert$ $d' = 1.28 + 0.52$ $d' = 1.8$	**Participant B's Sensitivity** $d' = \lvert Z(P(H)) \rvert + \lvert Z(P(FA)) \rvert$ $d' = 1.28 + 0.25$ $d' = 1.53$

Table 3: *Sensitivity Calculations*

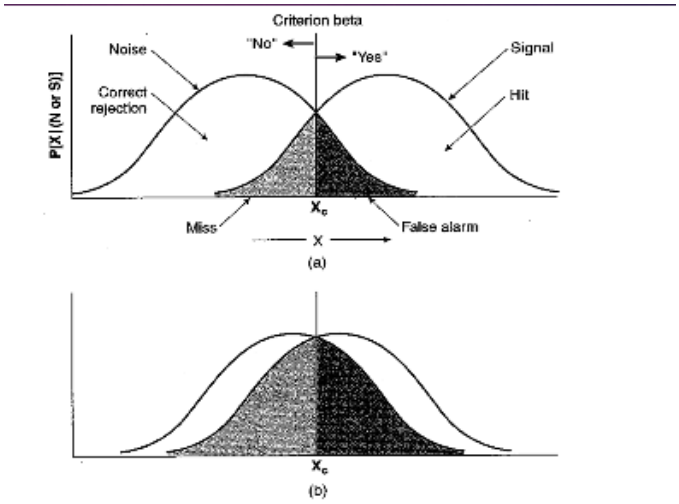


Figure 8: *Hypothetical distributions for SDT (a) High Sensitivity (b) Low Sensitivity*

VII. DISCUSSION AND CONCLUSION

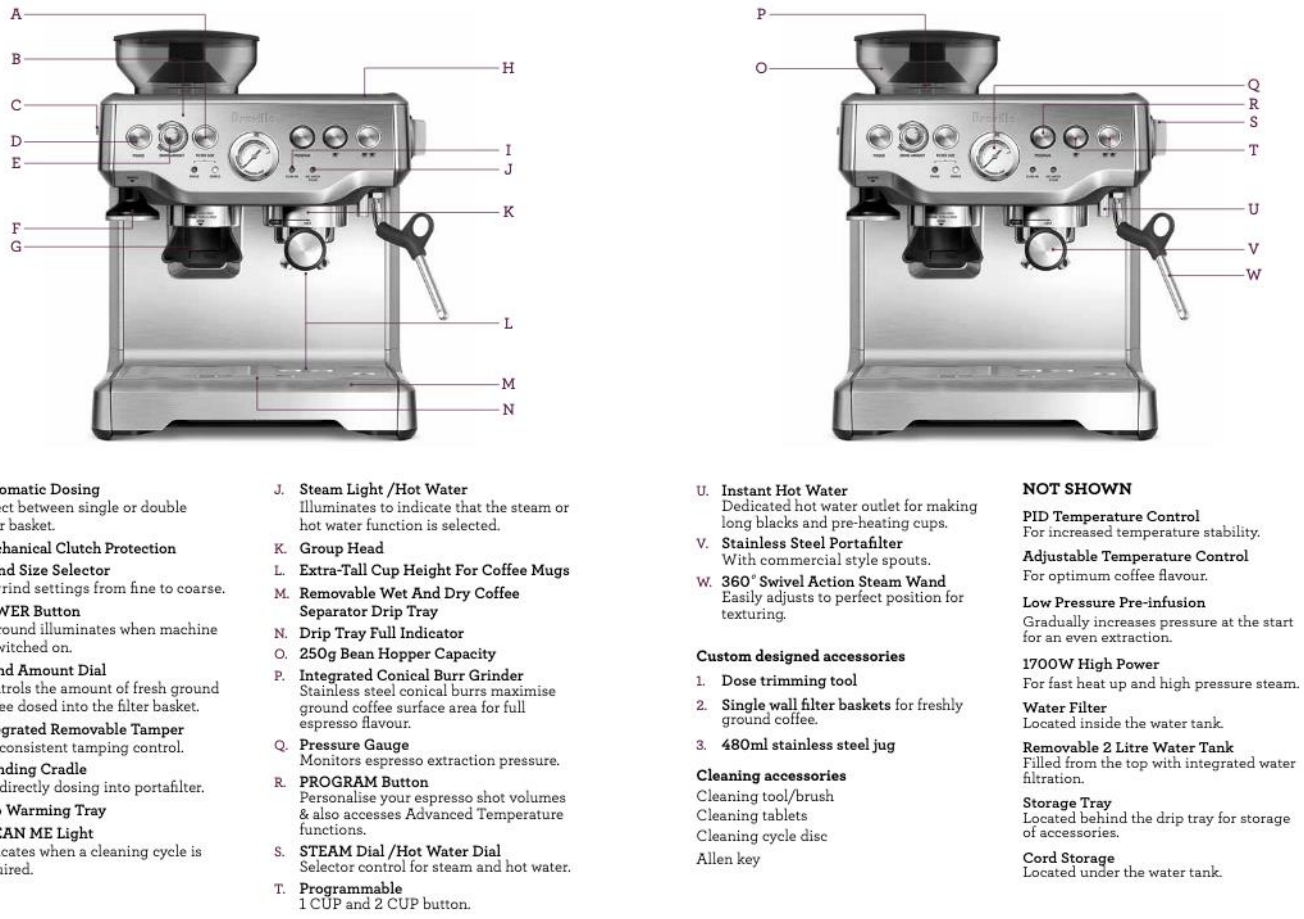
The main motivation for pursuing signal detection theory for an espresso machine was to determine the user's sensitivity towards the machine, in other words, to determine how well Breville Barista Express can help the user distinguish between good espresso and bad espresso. Sensitivity calculations (Refer to Table 3) showed that Participant A (*d'=1.8*) showed a slightly higher sensitivity than Participant B (*d'=1.53*). It is understood that the above calculations are subjective because of top-down influences on both individuals like preferred shot strength, taste buds, and more importantly, perception of 'good' vs 'bad'. Additionally, each participant conducted 10 replications each, which is not a high count for sensitivity calculations. In the future, increasing the number of replications for each participant can provide a more precise sensitivity value.

In conclusion, Breville Barista Express effectively enables the user in differentiating between a good espresso shot and a bad one. Overall, the machine is adaptable and learnable for users who are novel to the machine interface. The interface and the buttons are well thought-out and account for different kinds of problems that can arise during the espresso making process. Although the sensitivity of the machine was higher for Participant A than for Participant B, the overall sensitivity of the machine was generally high because of relatively higher probability of hits compared to misses or fails alarms. This can be verified by performing the same experiment with a higher number of replications.

VIII. REFERENCES

1. (2020) *Breville BES870XL Barista Express Espresso Machine, Brushed Stainless Steel*. Retrieved from Amazon: https://www.amazon.com/Breville-BES870XL-Barista-Express-Espresso/dp/B00CH9QWOU
2. Breville User Manual (2012). *The Barista Express: Espresso Machine.*

IX. APPENDIX



A. **Automatic Dosing**
Select between single or double filter basket.

B. **Mechanical Clutch Protection**

C. **Grind Size Selector**
18 grind settings from fine to coarse.

D. **POWER Button**
Surround illuminates when machine is switched on.

E. **Grind Amount Dial**
Controls the amount of fresh ground coffee dosed into the filter basket.

F. **Integrated Removable Tamper**
For consistent tamping control.

G. **Grinding Cradle**
For directly dosing into portafilter.

H. **Cup Warming Tray**

I. **CLEAN ME Light**
Indicates when a cleaning cycle is required.

J. **Steam Light /Hot Water**
Illuminates to indicate that the steam or hot water function is selected.

K. **Group Head**

L. **Extra-Tall Cup Height For Coffee Mugs**

M. **Removable Wet And Dry Coffee Separator Drip Tray**

N. **Drip Tray Full Indicator**

O. **250g Bean Hopper Capacity**

P. **Integrated Conical Burr Grinder**
Stainless steel conical burrs maximise ground coffee surface area for full espresso flavour.

Q. **Pressure Gauge**
Monitors espresso extraction pressure.

R. **PROGRAM Button**
Personalise your espresso shot volumes & also accesses Advanced Temperature functions.

S. **STEAM Dial /Hot Water Dial**
Selector control for steam and hot water.

T. **Programmable**
1 CUP and 2 CUP button.

U. **Instant Hot Water**
Dedicated hot water outlet for making long blacks and pre-heating cups.

V. **Stainless Steel Portafilter**
With commercial style spouts.

W. **360° Swivel Action Steam Wand**
Easily adjusts to perfect position for texturing.

Custom designed accessories

1. **Dose trimming tool**
2. **Single wall filter baskets** for freshly ground coffee.
3. **480ml stainless steel jug**

Cleaning accessories

Cleaning tool/brush
Cleaning tablets
Cleaning cycle disc
Allen key

NOT SHOWN

PID Temperature Control
For increased temperature stability.

Adjustable Temperature Control
For optimum coffee flavour.

Low Pressure Pre-infusion
Gradually increases pressure at the start for an even extraction.

1700W High Power
For fast heat up and high pressure steam.

Water Filter
Located inside the water tank.

Removable 2 Litre Water Tank
Filled from the top with integrated water filtration.

Storage Tray
Located behind the drip tray for storage of accessories.

Cord Storage
Located under the water tank.

Figure 9: *Detailed Breakdown of Machine Components*