A comparative analysis of neuromarketing methods for brand purchasing predictions among young adults

Urszula Garczarek-Bąk¹ · Andrzej Szymkowiak¹ · Piotr Gaczek² · Aneta Disterheft³

Revised: 19 March 2020 / Accepted: 10 November 2020 / Published online: 12 January 2021
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Abstract

Until now, neuromarketing studies have usually been aimed at assessing the predictive value of psychophysiological measures gathered while watching a marketing message related to a particular product. This study is the first attempt to verify the possibility of predicting familiar and unfamiliar brand purchases based on psychophysiological reactions to a retailer television advertisement measured by EEG, EDA and eye-tracking. The number of private label products chosen later served to assess the binary dependent variable. A logistic regression model (with a prediction rate of 61.2%) was applied to determine which psychophysiological variables explained the largest part of the variance of a final purchase decision. The results show that among various measures, only the electrodermal peaks per second were significant in predicting further purchase decisions. The decision to buy was also influenced by brand familiarity. The article concludes that EDA is an unobtrusive measure of emotion-related anticipation of significant outcomes, particularly for dynamic stimuli, as related to decision-making.

Keywords Decision making · Marketing communication · EEG · EDA · Eye-tracking · Neuroscientific methods

Introduction

Predicting consumer purchase behaviour is still one of the biggest challenges faced by marketers around the world, which has become especially more difficult as consumers are constantly being exposed to new technologies, products and wants. There is growing empirical evidence regarding the usefulness of applying neuro and psychophysiological measures into predictive models of purchase decisions (Yoon et al. 2012). According to Telpaz et al. (2015), neuroscience reveals information about consumer preference that is unobtainable through conventional methods, and neural activity can predict preferences of consumer products. Using neurophysiological measures (recording metabolic

or electrical activity in the brain) without recording brain activities to probe consumer minds directly, without the attrition of conscious participation, enables discovering the consumers' real emotions, feelings, expectations and even hidden restraints (Lin et al. 2018). Ariely and Berns (2010) underlined the prominent hope that neuroimaging will both streamline marketing processes and save money, because it will provide a more efficient trade-off between costs and benefits. The cost of performing neuroimaging studies would be outweighed by the benefit of improved product design and increased sales obtained through brain imaging, which could highlight not only what people like, but also what they will buy. On the other hand, the use of advanced neuromarketing techniques (e.g. fMRI) is relatively expensive, time-consuming and involves larger teams of researchers. Therefore, the question arises whether the added value of using them (i.e. more precise prediction of buyers' decisions) is worth the higher expenditure.

In this paper, we aim to compare, inform and triangulate results from available neuromarketing-related measurements, such as electroencephalography (EEG), electrodermal activity (EDA) and eye-tracking (ET) data in order to see which could serve as the best predictor of a product choice. Moreover, we test whether these techniques are better predictors of purchase compared to traditional

✉ Andrzej Szymkowiak
andrzej.szymkowiak@ue.poznan.pl

¹ Department of Commerce and Marketing, Institute of Marketing, Poznań University of Economics and Business, ul. Niepodległości 10, 61-875 Poznań, Poland

² Department of Marketing Strategies, Institute of Marketing, Poznań University of Economics and Business, ul. Niepodległości 10, 61-875 Poznań, Poland

³ Qiagen Business Services, Powstańców Śląskich 95 Sky Tower, 53-332 Wrocław, Poland

self-reports. Thus, we address the issue of marketing value of neuro-based techniques in product selection and provide managerial implications on how brand managements should approach consumer research to maximize effectiveness and predict behaviour with the highest accuracy. Our conclusions will be valuable for marketers looking for a guide on the most effective composition of measurement instruments in marketing research.

Our text distinguishes itself from others mainly because it links psychophysiological reactions to ads with brand choice (familiar vs. unfamiliar), while the majority of studies are focused on emotional and cognitive responses, and product but not brand choice (Harris et al. 2018). We contribute to the existing advanced knowledge by showing which measurements are effective in brand choice prediction influenced by video advertisements.

Literature review

Electroencephalography in predicting purchase decisions

Measuring electrophysiological responses enables the gathering of immediate feedback to presented stimuli in the form of fluctuations of brain signal frequencies (Brown et al. 2012). Using a different methodological approach to investigate positive versus negative emotional experiences, neuromarketing studies are based on the idea that there is a left–right asymmetry of the frontal EEG signals. Greater relative left frontal EEG activity is routinely associated with the processing of positive effects (an indication of happiness or amusement), whereas greater relative right frontal EEG activity is consistently linked with the processing of negative effects (e.g. indicating disgust) (Davidson et al. 1990).

Empirical evidence provides strong support for the predictive value of EEG measurement in product preference formation. This is due to the possibility of capturing approach-withdrawal motivation, which reflects consumer desirability of a product (Ohme et al. 2010). Product preference is reflected in brain activity observed at the moment of exposition to an advertisement (Wei et al. 2018) and to the product itself (Telpaz et al. 2015; Khushaba et al. 2013). Moreover, the use of EEG creates an opportunity to predict the attractiveness of marketing communication, e.g. advertising, and thus allows to formulate conclusions about its effectiveness (Gauba et al. 2017; Maison and Oleksy 2017; Ohme et al. 2010). Researchers claim that EEG can provide inform about one's interest in a commercial (Piwowarski 2018) as well as the emotional experience while watching it (Vecchiato et al. 2014; Ambler 2015).

EEG efficiency is also demonstrated in brand selection research (see Table 1). Similarly to product selection, neural

activity reflects a consumer's attitude towards a brand and translates into subsequent purchase intention. In the available literature, it is shown that brain activity can reveal the subjective emotional value that a brand has for a decision-maker (Pozharliev et al. 2019; Ohme et al. 2010). It may also serve as an indicator for a shift in brand preference caused by a TV advertisement (Silberstein and Nield 2015). Importantly, brand processing is associated with frontal region activity (Lucchiari and Pravettoni 2012); thus, based on EEG measurement marketers can conclude if the brand (e.g. exposed in a commercial) attracts consumer's attention (Wang et al. 2016).

Electrodermal activity in predicting purchase decisions

EDA, referring to the variation of the skin's electrical properties in response to sweat secretion, may be an appropriate method for engaging stimuli, similar to movie trailers (Benedek and Kaernbach 2010). According to Bradley and Lang (2000), EDA is a great physiological correlate for representing emotional arousal using a variety of different ways to elicit emotion (skin conductance responses occurring in a predefined response window, typically 1–3 s or 1–5 s after the stimulus, are attributed to the stimulus) (Dawson et al. 2007). Ravaja (2004) explained that changes in skin conductance (SC) indicate autonomic nervous system activation: the higher the SC levels, the higher physiological arousal. Boucsein (2012) reported that humans have lower EDA with positive emotions while negative emotions are associated with higher EDA. Furthermore, EDA can reveal unnoticeable emotions in browsing experiences.

As emotional arousal is a significant indicator of product and brand preference (Reimann et al. 2012; Gaczek 2015), EDA measurement makes it possible to predict whether a product or brand will meet buyers' interest (see Table 1). Interestingly, EDA research reveals that brands may be as arousing as close friends and elicit more positive valence than interpersonal relationships (Langner et al. 2015). On the other hand, research is inconclusive on the specific influence that known or loved (vs. unknown or disliked) brands have on emotional arousal. For instance, Walla et al. (2011) demonstrated that arousal was significantly reduced in the case of viewing liked brand names compared to viewing those disliked (suggesting that visual perception of liked brand names elicited a more relaxing state compared to disliked brand names). A similar finding is reported by Reimann et al. (2012) who claimed that the difference in arousal is due to the recently formed brand relationship versus already established relationships.

To the contrary, Smith et al. (2019) demonstrated children are more aroused when presented with their favourite branded products compared to the same products but without

Table 1 Psychophysiological measures used in brand perception and selection

Authors	Sample size	Mean age (SD)	Measurement	Findings
Ohme et al. (2010)	45	34.84 (5.83)	EEG	Frontal asymmetry predicts approach/avoidance tendencies towards brand and product
Pozharliev et al. (2019)	40	22.07 (2.09)	EEG	Neural activity differs because of exposition to luxurious (vs. basic) brands which are associated with greater emotional value
Silberstein and Nield (2015)	129	38.2	Steady-state topography (SST)	SST can be used to predict consumer's shift in brand preference following a tv advertisement
Garczarek-Bak and Disterheft (2018)	21	25	EEG, ET, EMG, EDA	Frontal asymmetry reflects differences in approach/avoidance behaviour towards national and private brands and can translate into product choice, while ET, EDA and EMG do not increase predictive value of the model
Khushaba et al. (2013)	18	38	EEG	Brain activity (especially in frontal, temporal and occipital regions) reflects an indication of preference for a product
Lucchiari and Pravettoni (2012)	26	24.5 (2.4)	EEG	Brand processing is associated with the activity of the frontocentral reward-related network. Specifically, the same product can elicit different frontal region activity when brand label is changed
Wang et al. (2016)	30	23.8	EEG	Frequency of exposure of branding products in video commercial influences the frontal delta and gamma rhythms associated with attention and perception. The results suggest that single exposure leads to a high level of attention to the product, while multiple exposure may enhance preference for the product
Walla et al. (2011)	21	28.14 (6.29)	EDA, EMG, HR	Skin conductance was reduced for viewing liked brands (compared to those disliked), suggesting that liked brands may elicit feelings of relaxation
Langner et al. (2015)	60	24.12 (2.64)	EDA	Brand love is less arousing compared to interpersonal love but loved brands may be as arousing as close friends and elicit more positive valence than interpersonal relationships
Maxian et al. (2013)	56	21	EDA, HR, EMG	No statistically significant differences between psychophysiological responses to more loved versus less loved brands, although the difference in self-reported arousal was statistically significant
Reimann et al. (2012)	17	Students	EDA	Increased emotional arousal for a recently formed close relationship with a brand but not for relationships already established. However, this finding is not supported by self-reports
Smith et al. (2019)	48	9.2 (1.07)	EDA	Children are more aroused when presented with their favourite branded products compared to the same products but without branding. Emotional responses to brands were similar as in the case of response to children's family and friends

Table 1 (continued)

Authors	Sample size	Mean age (SD)	Measurement	Findings
Gangadharbatla et al. (2013)	60	20.02	EDA	There was no interaction between emotional arousal elicited by brands presented on billboards in a video game or further recall of those brands
Pieters and Warlop (1999)	54	20–49	ET	By examining the relationship between attention and brand choice, the authors confirmed gaze bias and observed that consumers were more likely to choose those brands on which they fixated more
Wedel and Pieters (2000)	88	19–52	ET	Brand element surface attracted more attention compared to pictorial and text elements which enhance brand memory
Teixeira et al. (2010)	38	26	ET	Repetition of brand elements during short time intervals enhances attention to the brand and minimizes zapping, while long and uninterrupted brand exposition promotes zapping
Chandon et al. (2002)	159	24–65	ET	Brand recall was driven more by brand familiarity than actual attention paid to the brand at the moment of task choice
Underwood et al. (2001)	128	18+	ET	Package pictures increased attention paid to the brand, but only for those non-familiar
Chandon et al. (2009)	344	24–69	ET	Consumer visual attention was driven by the number of shelf facings which translates into brand evaluation, respectively, for frequent users of the brand and for low market-share brands
Krajchich and Rangel (2011)	30	Students	ET	Items that were fixated on more were more likely to be chosen, which contributed to quality of the choice process
Graham and Jeffery (2012)	203	42.24 (12.71)	ET	Participants looked longer at labels on products which they ultimately decided to purchase
Oliveira and Giralaldi (2019)	178	20.58 (2.29)	ET	Visual attention captured with ET is different for weak and strong brands

branding. In turn, Gangadharbatla et al. (2013) claimed no interaction between emotional arousal elicited by brands or further recall of them. In a comparative study on the predictive value of neuromarketing tools, Garczarek-Bąk and Disterheft (2018) suggested that the use of EDA does not translate into a better prediction of brand choice.

Eye tracking in predicting purchase decisions

Another psychophysiological measure providing an unobtrusive means of pairing the EDA data or EEG data with the applied stimuli is eye-tracking (ET). Through ET, it is possible to visually document a consumer's journey during the whole study. Within the context of visual choice and comparison tasks, monitoring the distribution and duration of eye fixations may provide an excellent measure of an observer's interests and preferences (Glaholt et al. 2009).

Precisely, these authors found evidence that the amount of time the eye spends on a chosen stimulus is positively related to the likelihood of that stimulus being selected and preferred.

Moreover, it is also documented that visual attention towards brand-related elements (e.g. labels) corresponds to general attitude towards the brand (Graham and Jeffery (2012). According to Venkatraman et al. (2015), ET, used as a direct measure of attention, is probably the most accessible method for catching ad response, which enables capturing not only which information was processed, but also the order and duration of these processes. Oliveira and Giralaldi (2019) come to similar conclusions by demonstrating that visual attention captured with ET is different for weak and strong brands. More specifically, the percentage of valid fixations provides an index of overall attention or engagement with the ad, while the number of fixations and mean dwell times

provide a measure of the depth to which information within an ad is processed.

Brand familiarity in marketing and neuroscientific research

Consumer attitudes towards a brand play a major contributing role regarding purchase decision (Bosshard et al. 2016). Familiar brands receive more favourable evaluations and consumers are more likely to consider them for future purchases (Sundaram 1999). Hoeffler and Keller (2003) noted that strong (familiar) brands have been suggested to have stronger and more positive brand associations compared to unfamiliar brands, and due to the greater number of associations in a wide variety of contexts, they are more likely to be in consumers' consideration sets. As explained by Esch et al. (2012), strong positive associations should further contribute to positive feelings (in terms of recalling past consumption experiences), which may trigger strong sensations such as brand attachment, trust and excitement. Lim and Chung (2014) explained that for familiar brands, consumers are likely to be highly certain of their evaluation due to the fact that they may have had prior experience using the brands, seen the advertising or marketing communications, received information from the news media, or experienced word-of-mouth from friends and family. As noticed by Janiszewski et al. (2013), consumers are more likely to purchase a product if they have previously focused their attention on it. The act of attending to a product available and well known on a certain market may increase the likelihood that the product be chosen in the future.

Interestingly, consumers with prior brand familiarity are more likely to attenuate the influence of attitude towards the specific ad on attitude towards the brand (Campbell and Keller 2003). Therefore, the ad's attitude effect on brand evaluations should be greater when the ad is for an unfamiliar brand, and consumers process an unfamiliar brand ad more extensively (Machleit et al. 1993). According to Campbell and Keller (2003), ads for unfamiliar brands may seem less boring; however, they can wear out more quickly than for ads more familiar. Additionally, attitudes engendered by an ad are less likely to influence attitudes towards familiar brands.

According to Reimann et al. (2012), insight into the psychological processes underlying the choice of novel versus familiar brands can enable a better understanding of consumer choice and evaluation processes. However, brain imaging has been used to a significantly lesser extent in determining the neurophysiological keystone of novel brands. Accessing psychological processes towards them is difficult because consumers have typically not yet formed any associations or attitudes while lacking certainty about their evaluation of unfamiliar brands. As mentioned by Ravaja et al. (2013), brand associations are formed when

interacting with the brand (e.g., trips to shops and actual consumption), and during prior indirect brand exposures (e.g., via brand communications). In the EEG research conducted by de Azevedo (2010), only the familiar brands elicited activations in the frontal cortex during the first second following logo presentation (meaning that the frontal cortex was exclusively activated for familiar brands, revealing the importance of brands as meaningful symbols that convey a specific message). Moreover, the mean potential measured in the LPP interval revealed stronger activations in the centroparietal regions for the most preferred brands when compared to the unknown brands, suggesting that they were given more attention and were more self-relevant.

On the contrary, the unknown brands elicited more activation in the occipital cortex and frontocentral region. Surprisingly, the results of the asymmetries showed a pronounced right-hemisphere Alfa band power (p value of $< .05$) for every group of response rating (meaning stronger left brain activation). Further attempts using the activity in the frontal cortex and its asymmetry in predicting the choice of purchasing a product proved that 95% of the respondents chose well-known brands and found a dominance trend of the left hemisphere over the right in the oral statements of the tested participants (Olarie 2017). In the case of electrodermal research, Walla et al. (2011) revealed that skin conductance data demonstrate a clear sensitivity related to subjective brand preference, while skin conductance was markedly reduced in the case of visual perception of liked brand names (versus disliked brand names), which may suggest that visual perception of liked brand names elicited a more relaxing state (Plassmann et al. 2015). These results may suggest that consumers use experienced emotions rather than declarative information to evaluate familiar and unfamiliar brands.

Study 1

According to a quite rich body of empirical evidence implementing neurophysiology (as an additional tool, but not as a replacement method) leads to significantly better accuracy and greater predictive power compared to self-reports alone. However, based on our knowledge of prior works, there is still scarce research incorporating various neurophysiological methods with the aim of assessing their predictive values in terms of purchase decision-making. Thus, in this study, we aim to compare, inform and triangulate results from relatively inexpensive and available neuromarketing-related measurements, such as EEG, EDA, ET data and self-report measures in order to probe which can serve as the best predictor of a product choice. Simultaneous measurements of psychophysical reactions made by applying various devices were necessary

to compensate for individual differences, which would be associated with the occurrence of type II errors.

Participants

The participants were twenty-four healthy, right-handed students and graduates of Poznań universities, among them 10 females, all born in Poland, within the age range of 21 to 34 years, at the average age of 26. Due to the breaks in the recorded signal, five individuals had incomplete data and were discarded from the analysis. The final dataset included 19 participants with valid and reliable data. Although there is no one sample size appropriate for all neuromarketing studies, and the sample size depends on multiple factors including research objectives and study design (Bojko and Adamczyk 2010), the reasonable minimum sample size in single consumer preference studies was 12 subjects in by Kostoulas et al. (2015) on EDA research, 15 subjects in the EEG research by Telpaz et al. (2015) and 16 subjects in ET research (Glaholt and Reinhold 2011). In case of combined experiments, Khushaba et al. (2013) used a sample of 18 participants in EEG and ET research (Sheng and Joginapelly 2012)—20 participants in EDA and ET research and Cartocci et al. (2017)—22 participants in EEG and EDA research.

Individuals were invited to voluntarily participate in the experiment by subscribing to a list via the Internet. The main restrictions concerning participation and recommended preparation guidance (e.g., not to consume alcohol, caffeine or smoke cigarettes before the experiment, to avoid using hair styling products and sleep at least 8 h) were expressed over the telephone. A determinant criterion at recruitment was shopping on a weekly basis at supermarkets, which guaranteed that participants were aware of the existence of private label products. Respondents were paid a fixed fee of 100 PLN (\$25) for their participation in the study.

Design and procedure

The research project was approved by the Ethical Committee at Poznań University of Economics and Business. The study was conducted in the Consumer Research Laboratory at PUEB and took approximately 30 min (including the EEG, ET and EDA equipment preparation and calibration).

According to the results obtained by Teixeira et al. (2014), familiar ads and brands (regarded as entertaining) are presumed to be more likely associated with higher reported purchase intent and choice. Therefore, research was structured in two blocks. The former included five chain-store ads from shops available in the participants' country of residence, and the latter comprised chain stores operating in America (according to declarations—unfamiliar to participants). All stores were selected on the basis of the highest annual revenues in 2017. Chain-stores operating in America were chosen for this study as they do not operate in Poland; thus, they are unfamiliar to participants. We could not choose the top 5 stores operating in Europe as those chains are already present in Poland (e.g. Schwarz, Aldi, Carrefour, Tesco). Moreover, it was important to choose chain-stores that provided their marketing communication and product packages in English, as most young Polish adults are used to buying products with English labels.

In the first block (see Fig. 1), participants watched video commercials five familiar brands. After viewing each ad, on a grey screen, they were asked to rate their overall Ad Attitude ("How did you like the ad?") on a 7-point Likert scale and Brand Attitude (non-appealing/appealing, dislikable/likable, unfavourable/favourable) on a 7-point semantic differential scale. After watching and rating five ads, they were asked to make 10 purchase choices with the click of a mouse. Every time they were shown a board with five private label products of the same FMCG category, from a different, previously advertised, chain store. The second block had the same command, but based on five unfamiliar retailers' ads and making 10 purchase decisions among the American

Fig. 1 Experimental flow chart

private label products. Dependent and independent variables are presented in Table 2.

Stimuli

In research, it is suggested that to a certain point the increment of positive elements in television advertisements can make them more attractive and persuasive, hence heightening purchase intentions and product choice, but an excessive load of entertainment can actually reduce the ad's persuasiveness (Teixeira et al. 2014). Further, depending on whether the entertaining elements appear before or after the appearance of the brand, the product choice varies (in favour of ads that evoke positive emotions after a brand exposure). Having this in mind, real retailers' TV advertisements with a moderate level of positive emotional charge and a brand that appears at the end were chosen for the study. They were also of comparable length (15–30 s) in order to reduce the possible impact of the ad length on product choice (there was a new variable created in order to account for different ad length).

Keeping in mind that involvement in a category is significantly related to product choice even once we endogenously control for viewing interest, the used stimuli include product choice for different product categories from FMCG (both food and hygienic products: corn flakes, jam, yogurt, juice, milk, dish soap, liquid soap, shower gel, tissues, toilet paper). All products within a certain category have comparable taste, smell, and similar packaging. Private label products were selected deliberately for the prevention of a new variable introduction.

For apparatus and data analysis description, see Appendix 1.

Results

The Mann–Whitney U test revealed that there were no significant results between the declared Number of Chosen Products (NCP) regarding familiar and unfamiliar brands [$Z(165) = -.450, p = .652$]. Seven psychophysiological metrics from ET, EEG and EDA measurements, as well as two self-reported measures, ad and brand attitude, were tested for correlations with the total number of products chosen from a particular store. Alpha asymmetry for three bands and the number of electrodermal responses correlated with the amount of chosen goods (see Table 1).

Further analysis based on divided subsets, familiar and unfamiliar brands, revealed that the Number of Chosen Products was weakly correlated with EDA Peaks Per Second [$r_s(69) = .252, p = .018$] and with Brand Attitude [$r_s(69) = .279, p = .010$] only for familiar brands. Next, a nonparametric test was performed in order to check for differences in psychophysiological data for both brand types. Seven analysed variables from the Mann–Whitney test revealed significant differences across brands for Average Pupil Size [$t(165) = -3.953, p < .000$], Number of Fixations [$t(165) = -4.553, p = .000$], and EDA Peaks Per Time [$t(165) = -3.995, p < .000$].

Interestingly, as the pupil size was larger for familiar brands, which may reflect the engagement of cognitive effort connected with bringing more brand association (while processing all of them, the cognitive load is greater). However, the higher number of fixation points measured for unfamiliar brands represents cognitive processes for unfamiliar advertisements (which may be interpreted as attracting respondents' absolute attention to the ads or representing a misunderstanding to a certain degree). Higher EDA frequency peaks for unfamiliar brands, associated with emotional arousal to stimuli, may indicate stronger mental arousal while watching unknown commercials.

Finally, after rejecting the assumptions of linear regression, in order to search for potential nonlinear relationships

Table 2 Dependent and independent variables used in the study

Experimental stages	Stage 1. Commercial exposition			Stage 2. Ad and brand assessment		Stage 3. Product choice task
Independent variables	Brand familiarity (familiar vs. unfamiliar)					
Dependent variables	Visual attention	Brain activity	Emotional arousal	Ad attitude	Brand attitude	Number of chosen products
Measurement	Average pupil size; number of eye fixations	Frontal alpha asymmetry; frontal beta asymmetry; frontal gamma asymmetry	EDA peaks per second; EDA amplitudes	7-point Likert scale		Product choice

between the number of chosen products and psychophysiological measures, backward elimination (conditional) logistic regression was performed. The binary Private Label Purchase (PLP) variable was computed by dichotomising the Number of Chosen Product score using the median split (more than 2, the median value was described as “a lot”). Variables included in the first step contained neurophysiological measures: two oculomotor characteristics, three frontal asymmetry indexes and two electrodermal activity related measures.

The final model consists only of EDA Peaks Per Seconds (in the zero step: $p = .047$, score = 3.954) and Retailer Store Visitor ($p = .272$, score = 1.208). The Backward elimination approach in stepwise regression was as follows (parameters from step 0): EDA Amplitudes (.371, $p = .543$), Number of Fixations (.139, $p = .710$), Average Pupil Size (.564, $p = .453$), Frontal Alpha Asymmetry (.191, $p = .662$), Frontal Beta Asymmetry (.195, $p = .659$), and Frontal Gamma Asymmetry (.238, $p = .626$). Therefore, to predict the probability of private label purchases, the following model may be applied:

$$\text{logit(PLP)} = -2.609 + 5.028 \times \text{EPS} + 0.891 \times \text{RSV}.$$

The log of the PLP odds was positively correlated with EDA Peaks Per Second ($p = .017$), meaning the higher the number of EDA Peaks Per Second, the more likely that a private label product will be bought. A score one point higher in the EDA peaks per second will increase the odds of a private label purchase by fivefold (that is, one more peak per second would result in the probability of a purchase being five times higher). Giving the same EPS score, familiar brands were more likely to be chosen than unfamiliar ones (they were coded as 1). In fact, the likelihood of choosing products of a familiar brand product was 2.44 times greater than for unfamiliar brands. The model evaluation is presented in Table 2.

The overall model is significant ($p = .043$) with the Chi-square statistic of 7.548. The inferential goodness-of-fit test yielded a χ^2 (8) of 10.345 and was insignificant ($p > .05$). The overall correction of the prediction was 62.4%. With the cutoff set at .5, the prediction for respondents who did not intend to buy was more accurate than for those who did (86.9% and 15.6%, respectively). The accuracy of the diagnostic test was 61.2%, and it is shown as the area below the ROC curve presented in Fig. 2.

Fig. 2 Receiver operating characteristic curve for the brand purchase. Note dashed line—reference line. AUROC = .612. SE = .048. $p = .018$

Due to the lack of predictive models for familiar and unfamiliar brands, by comparison, the model of predicting audience responses to movie content from EDA measurement by Silveira et al. (2013) provided 72% accuracy (offering a 31% improvement over predictions from demographics alone).

Following, in order to increase knowledge about brand familiarity importance, separate models for predicting private label purchases for familiar and unfamiliar brands were built using the same statistical tools and variables. In Table 3, all variables included in the zero step of a logistic regression are presented for both familiar and unfamiliar brands (distribution was made based on declarations provided by respondents regarding the Retail Store Visitor variable). In the case of familiar brands, all variables related to EDA and ET were gradually eliminated from the regression model. In the event of unfamiliar ones, on the other hand, only one variable related to EDA (EDA amplitudes) was eliminated from the model (Tables 4, 5, 6).

Familiar brands model

For familiar brands, only the frontal asymmetry variables (for alpha, beta and gamma bands) remained in the fifth step of regression proposing the following model [however, at an insignificant level (.259; .258; .251, respectively)]:

$$\text{logit(PLP)} = -0.087 + (8750.183 \times \text{FAA}) + (-9659.070 \times \text{FBA}) + (908.969 \times \text{FGA}).$$

Table 3 Correlation between psychophysiological and self-report measures, and the number of chosen products

Measure	1	2	3	4	5	6	7	8	9	10
1. Average pupil size	–									
2. Number of fixations	.206**	–								
3. Frontal alpha asymmetry	–.142*	.192**	–							
4. Frontal beta asymmetry	–.142*	.193**	1.000**	–						
5. Frontal gamma asymmetry	–.138*	.196**	1.000**	1.000**	–					
6. EDA peaks per second	.000	.215**	.092	.093	.091	–				
7. EDA amplitudes	.256**	–.065	.120	.119	.118	.174*	–			
8. Ad attitude	.058	.087	.029	.030	.029	.009	–.039	–		
9. Brand attitude	.085	.029	–.012	–.011	–.012	–.023	–.151	.779**	–	
10. Number of chosen products	.036	.000	–.138*	–.137*	–.136*	.144*	.026	.107	.147*	–

* $p < .05$; ** $p < .01$ (1-tailed)**Table 4** Predictors and test of the logistic regression model

Predictor	<i>B</i>	SE	Wald	<i>df</i>	Sig.	Exp(<i>B</i>)
EDA peak per second	5.028	2.109	5.682	1	.017	152.642
Retailer store visitor	.891	.489	3.313	1	.069	2.437
Constant	–2.609	.816	10.221	1	.001	.074
<i>Test</i>			Chi square	<i>df</i>	Sig.	
Overall model evaluation			7.548	1	.043	
Goodness-of-fit test—Hosmer and Lemeshow			10.345	8	.242	

Cox and Snell $R^2 = .078$. Nagelkerke $R^2 = .108$ **Table 5** Variables included in the logistic regression model and their removal sequence

Variables	Familiar brands				Unfamiliar brands			
	Score	<i>df</i>	Sig.	Removal sequence	Score	<i>df</i>	Sig.	Removal sequence
EDA amplitudes	.140	1	.708	1	.058	1	.809	1
Average pupil size	.556	1	.456	2	.035	1	.852	
EDA peak per second	1.308	1	.253	3	6.004	1	.014	
Number of fixations	2.113	1	.146	4	1.750	1	.186	
Frontal alpha asymmetry	.087	1	.768		.400	1	.527	
Frontal beta asymmetry	.087	1	.768		.407	1	.524	
Frontal gamma asymmetry	.083	1	.773		.488	1	.485	

Table 6 Correlation between self-report measures and the number of products chosen

Measure	1	2	3	4	5	6
1. Pleasure	–					
2. Arousal	.310	–				
3. Dominance	.815**	.199	–			
4. Ad attitude	.787**	.261	.855**	–		
5. Brand attitude	.847**	.296	.788**	.652**	–	
6. Number of chosen products	–.085	.157	–.043	.064	.142	–

* $p < .05$; ** $p < .01$ (1-tailed)

Although the Hosmer–Lemeshow test results ($\chi^2 = 4.045$, 7 degrees of freedom, $p = .775$) indicated that the goodness-of-fit is satisfactory, the Nagelkerke R^2 value was .087, suggesting that the model is not very useful in predicting private label purchases, similar to the area under the Receiver Operating Characteristic (AUROC) for these data, which gave a value of 58% (indicating that the discrimination of the model is poor), while the model, after removing components, offers the significance of changes for .014, .013, and .012, respectively, the contribution of the three explanatory variables in the prediction of familiar private label purchase is still poor. The classification table explains 66.7% of purchase decisions (with the cutoff set at .5, the prediction for participants who did not intend to buy was more accurate than for those who did, at 85.2% and 27.8%, respectively).

Unfamiliar brands model

Interestingly, for unfamiliar brands, as many as six variables (except EDA amplitudes) remained in the second step of the logistic regression, creating the following model:

$$\begin{aligned} \text{logit(PLP)} = & -12.299 + (4.999 \times \text{APS}) + (-.064 \times \text{NOF}) \\ & + (-15440.124 \times \text{FAA}) + (16947.795 \times \text{FBA}) \\ & + (-1505.7530 \times \text{FGA}) + (14.137 \times \text{EPS}). \end{aligned}$$

This time, only the EEG measurements were statistically insignificant. Whereas eye-tracking variables were significant at the levels of .032 and .007, respectively, EDA Peaks Per Second (EPS) was significant at the .017 level and constant ($p = .035$). After removing components, the model indicating significance (with $p < .005$). Due to the fact that there is more than one explanatory variable in the model, the interpretation of the odds ratio for one variable depends on the values of other variables being fixed. The interpretation of the odds ratio for chosen variables should be performed on the basis of the following example: the odds ratio of 4.999 indicates that, for given levels of all variables, for a score one point higher in average pupil size, the odds of private label purchase is five times as great. Generally, the overall model was significant at the level of .001, with the Chi-square statistic of 28.259, and R^2 Nagelkerke = .635, indicating that the model is useful in predicting private label purchases. Moreover, the Hosmer–Lemeshow test ($\chi^2 = 3.905$, 8 degrees of freedom, $p = .866$) indicates that the numbers of chosen private labels are not significantly different from those predicted by the model and that the overall model fit is good. The overall correction of the prediction was 83.3%. With the cutoff set at .5, the prediction for participants who did not intend to buy was more accurate than for those who did (91.2% and 64.3%, respectively). The area below the ROC curve, quantifying the overall ability of the test to discriminate between an affirmative purchase decision

and a negative one, revealed that the accuracy of the test was 65.8%. Affirmative purchase decisions as well as negative ones revealed a test accuracy of 65.8%.

Follow-up study

In order to more extensively test the obtained results, we conducted a simple replication of the experiment described above. Its aim was to test whether self-reports regarding emotional experience predict product choice to the same extent as psychophysiological measures. This issue is addressed due to the fact that self-reports may not be accurate enough to capture the subtle nature of emotional and cognitive influence on product and brand choice (Ariely and Berns 2010). The experimental procedure was similar to experiment 1, but as COVID-19 emerged, the study was conducted online. Participants ($N = 28$) were exposed to the same stimuli as in experiment 1; however, we used the Self-Assessment Manikin Scale (Bradley and Lang 2000) to assess emotional experience with regard to 3 dimensions: pleasure (whether the elicited emotion is positive or negative), arousal (how much the elicited emotion is “exciting”) and dominance (if one feels “in control” of the emotion). We conducted correlation analysis between self-reported emotions and product choices used in the first experiment. The results indicate that the correlation between self-reported emotional experience and chosen products is not statistically significant ($p < .05$). Nonetheless, we observed a positive correlation between ad attitude (and brand attitude) and pleasure as well as dominance, suggesting that declared pleasure associated with the ad and perceived control translate into more favourable judgment of an ad and brand. Those, however, do not correlate with the number of chosen products.

Discussion

Based on our knowledge from prior work, the following research constitutes the first attempt (Nilashi et al. 2020) at incorporating various psychophysiological methods with the aim of assessing their predictive values in terms of purchase decision-making, interestingly, based on a brand advertisement rather than a particular product. The results of the present study comprise a further premise for the application of neuro and psychophysiological measures in predicting brand success (measured as the number of product purchases) while confirming its advantage over self-reports alone. Furthermore, this suggests that in the case of video advertisements of a general nature—focused on positive brand attitude formation, EDA may serve as an optimal solution in forecasting brand performance. What is interesting, unlike the study by Reimann et al. (2012), the different effects of

EDA measurement on purchase decision are confirmed depending on brand familiarity, since the EDA Peaks Per Second was linked to the higher probability of purchasing familiar brands.

As the products of both brand types (familiar and unfamiliar) used in the study had comparable packaging appearance and the commercials were the same informational type and of similar content, the different patterns of decision-making for familiar and unfamiliar brands were thoroughly studied. The EDA peaks correlate with declared private label product purchase but only for the familiar stores, which may be interpreted not as an advertisement “like” but rather how much consumers like the advertised brand itself (which must be previously known to respondents), whereas EEG frontal asymmetries correlated with the number of declared chosen products did not reveal a statistically significant relevance in terms of predicting a purchase. It may be suggested that it is a proper, universal measurement, but one that is not really suitable in terms of predicting consumer intentions based on dynamic stimuli. Through the lack of significance in ET metrics regarding the general model, it may be understood that brands were equally camouflaged amongst the commercials. The recommendations of this research are not meant to disregard all future intersections with EEG, ET and retailers’ evaluation. Instead, more tactics must be used to understand the connection between the brain, the body’s nervous system, and finally, consumers’ visual attention and their self-report measures. According to Bosshard et al. (2016), it is crucial to use a multidimensional approach and apply as many measures as possible (and reasonable in terms of financial matters) to quantify the various aspects of brand attitude, as brands themselves are considered to be multidimensional concepts.

The follow-up study supports the notion that self-reports alone are not sufficient enough to predict purchase decisions (Ariely and Berns 2010). On the other hand, we observed that self-reported pleasure and control enhance the favourable evaluation of ads and brands. Hence, we state that emotional ratings can translate into a brand and advertisement attitude, but they cannot be an accurate predictor of actual brand choice. Specifically, we emphasize that the implementation of neuromarketing techniques is particularly useful in predicting actual behaviour, while self-reports are sufficient in predicting explicate attitudes towards brands (Lee et al. 2007; LaBarbera and Tucciarone 1995).

Conclusion and managerial implications

While understanding and predicting how customers really think, feel, and respond to offers of a certain company has always been complex and problematic (Hsu 2017). Nowadays, consumer neuroscience enables researchers to obtain a

more objective understanding of consumers’ desires (Hubert 2010). Assessing the reaction of viewers to video content is important for a wide variety of applications, e.g. predicting the success of ad or brand campaigns (Silveira et al. 2013).

In this particular study, the number of chosen products of a given brand might be understood as an estimate of the future market share relative to competitive brands. Therefore, the investigation of EDA as a response to video ads may help assess market position and potential. Although the percentage of final purchases explained by the number of EDA responses is not very high, one may be satisfied with more general market performance estimates, namely whether the brand will perform better than the majority of other investigated brands.

The managerial implications resulting from the research relate to the effectiveness of neuromarketing research and the content of brand marketing communication. Firstly, we offer supportive evidence that that market researchers can potentially use EDA responses as a valid tool to measure video advertisement effectiveness in predicting consumers’ private label product choices. This implication also relates to a broader construct of emotional (but possibly to sexual as well) arousal that can be a better predictor of consumer behaviour than emotional valence (Coker 2020; Szymkowiak et al. 2020). Thus, marketers should not limit consumer research to assessing the positive versus negative dimensions of brand communication, but should also measure consumer excitement or arousal. On the other hand, more sophisticated and expensive neuro-techniques (e.g. EEG) should be chosen carefully, as their predictive value is scarce.

Secondly, as we observed emotional arousal is a significant predictor of product choice, marketers should design marketing communication to increase emotional stimulation associated with the brand. For example, ads evoking higher emotional arousal are better memorized (Bakalash and Reimer 2013) and evaluated more positively (Gorn et al. 2001). On the other hand, practitioners should carefully consider the context on which they display commercials. Newell et al. (2001) observed that programmes evoking strong emotional reactions (e.g. the Super Bowl) may inhibit the recall of ads or brand.

Further research would be recommended in order to determine further relationships between psychophysiological patterns and people’s reactions to persuasive stimuli. The investigation of the relation between facial expressions and measures of advertisement effectiveness would be interesting in terms of predicting consumers’ purchasing intentions concerning different types of products, although preferably not from the low-engaging category.

Limitations

The current study has some limitations that deserve to be addressed in further research. In this study, we look at the effects of commercials in the short term, of exposure to ten ads, when consumers form their preferences closely after watching ads (similarly as in the case of purchase intent measurement conducted by Teixeira et al. (2014). Although the chosen advertisements were similar in presented content and type of message (informational—not highly entertaining), there is still a risk that viewers may pay less attention to a message that is associated with a previously known brand, or in the absence of knowing the advertised retailer, they may associate the positive entertainment felt to the ad as opposed to transferring it to the advertised brand. Furthermore, TV commercials are dynamic stimuli including multiple events that can trigger different emotional reactions in a random time window (Lajante et al. 2012). Moreover, Reimann et al. (2012) pointed out that electrodermal activity data depend on length and closeness of the consumer's relationship with a brand and result in greater arousal at the beginning of a strong relationship and abate over time. However, in this case, the assumption that EDA may be more useful when studying new brands on the market was rejected because greater arousal was recorded while watching familiar commercials. The next issue is the fact that participants made actual choices during the EEG, ET, and EDA recordings. Therefore, according to Telpaz et al. (2015), it is still an open question whether EEG data during passive viewing of stimulus may be used in order to predict choices over some substantial time horizon. Finally, potential criticism may concern the applied equipment. With technological developments, modern apparatus may provide higher sampling frequency that allows for gathering more accurate results and presenting less inconvenience for the participants. However, it still does not reduce the participants' awareness of being observed, regardless of applying only single or a few neuro-marketing research devices.

Acknowledgements This work was supported by the National Science Centre (2014/15/N/HS4/01425, 2014/15/N/HS4/01326).

Appendix: Apparatus and data analysis

The registration phase was conducted in a neutral room in which the temperature (24 °C) and the brightness (artificial lighting) were kept constant. The stimuli were shown on a 25-inch monitor using OpenSesame, and SMI eye-tracking glasses with the 60 Hz sampling frequency were used to record eye movements. All signals were recorded and amplified using an 8-channel bipolar system (provided by g.tec) with a 256 Hz sampling frequency. EEG electrodes were

placed according to the 10–20 International Electrode Placement System on sites F3 and F4, with the ground electrode on Fz. The EDA signal was recorded from the forefinger and ring finger of the nondominant hand (left hand for all participants).

A MATLAB environment was used for signal preprocessing, artifact rejection, epoching, and further analysis. The EEG signal from the frontal lobe (F3 and F4) served to calculate the frontal asymmetry index for alpha (8–12 Hz), beta (13–25 Hz), and gamma (30–80 Hz) bands. Frontal brain asymmetry index in three bands (FAA, FBA, FGA) and two electrodermal responses (EPS—peaks per second and EAM—amplitude) were computed and analysed for every video ad and participant. Signal processing included notch filter (50 Hz) application, bandpass filtering (.01–1 Hz for EDA, 13–25 Hz for EEG), and smoothing. The threshold for EDR was computed individually based on the signal mean and standard deviation. Frontal asymmetries were computed using the following equation: example for alpha band: $FAA = \log(FPL - FPR / FPL + FPR)$, where: FPL—frequency power from left hemisphere; FPR—frequency power from right hemisphere. To reduce between-subjects differences in response magnitude, standardization of the recorded EDA data was necessary before performing most statistical tests. Due to the different time-dynamic stimuli, in order to compare the obtained results, there was a need to normalize the data and the new variable was computed by correlating the number of chosen products with the number of EDA peaks per second.

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Urszula Garczarek-Bąk is an Assistant Professor at Commerce and Marketing Department and Teaching Fellow at the Poznan University of Economics and Business, Poznan, Poland. She conducts research in the field of consumer neuroscience and neuromarketing, especially focusing on predictive models of purchase decisions.

Andrzej Szymkowiak, Ph.D. is an Assistant Professor at Department of Commerce and Marketing at Poznań University of Economics and Business (Poland) and he is also head of ConsumerLab.pl. His research has centred around consumer behaviour, digital marketing and

decision-making process. His current interests are social media marketing, omnimarketing strategy and managing data in digital marketing.

Piotr Gaczek is currently working at the Poznan University of Economics and Business as researcher and lecturer. He is also involved in Consumer Research Lab at PUEB. His fields of expertise mainly relate to behavioural and experimental economics; specifically, he is focused on emotional influence on consumer preference formation.

Aneta Disterheft Master in Cognitive Science and a Ph.D. in Management Science. Author of many research projects in the area of neuromarketing and consumer neuroscience, conducted at Consumer Research Laboratory, Poznan University of Economics and Business.