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Reflections on the Use of Psychophysiology in Studying Reading on Digital Media

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Abstract. This study reports the results of an experiment for studying the reading experience on digital media using frontal electroencephalographic (EEG) alpha asymmetry, an index of approach/withdrawal motivation. Natural reading of a newspaper on the traditional print medium and a tablet computer were compared. Reading the print newspaper induced relatively greater left frontal cortical activation, suggesting higher approach motivation during reading on paper than on a tablet. The observed differences are moderated by individual differences in personality type (BIS/BAS scales), reading style, and experience with a tablet computer. BAS Drive and Fun Seeking subscales showed a significant negative effect on frontal EEG asymmetry when reading on tablet; increases in the Drive and Fun Seeking scores predicted lower approach motivation. In addition, the analysis of reading profile and demographics showed that focused readers experienced greater approach motivation during reading the print newspaper and a higher experience with a tablet computer was not found congruent with higher approach motivation during reading on a tablet. Implications for information systems research and design practice are discussed.

Keywords: newspaper reading, reading medium, EEG, frontal asymmetry, BIS/BAS, personality, behavior-motivation, approach/withdrawal motivation

1 Introduction

The size and weight of computer tablets and the improvement in screen quality make reading from mobile devices increasingly acceptable (see, e.g., [1]). This form of

reading using digital media gains increasing popularity, especially among young people. According to a survey of newspaper readership in Finland, in autumn 2014, 70 percent of the young readers under 18 used mobile phone as a medium for reading newspapers and magazines; in contrast, the adults over 50 used a mobile phone platform for reading only in proportion of 17 percent [2]. One of the reasons of adopting the digital newspaper is the accessibility everywhere anytime, especially when a paper version is not convenient. However, according to [3], world-wide, there is still "a general reluctance to accept digital reading media stem".

In this paper, our aim is to investigate whether traditional and digital reading media elicit different kind of behavioral-motivation responses as measured by frontal electroencephalographic (EEG) alpha asymmetry. Frontal alpha asymmetry is an established index of approach/withdrawal motivation [4, 5], which is based on the theoretical and empirical findings by Davidson [e.g., see 6] that a higher level of left-hemisphere brain activity in the alpha frequency band (relative to the right-hemisphere brain activity) is associated with higher approach motivation behavior. Moreover, in the paper, we study also the moderating effects of individual differences such as personality, reading profile, and demographics on behavior-motivation responses. Thus, we report the results of an experiment for studying reading experience of a newspaper on digital media versus traditional print. After presenting the background of the study, the methods, and the results, we discuss the use of psychophysiological measures, such as frontal asymmetry, and the role of individual differences in explaining behavior-motivation towards digital media, in particular reluctance to digital media. Implications for research and practice of designing digital media and information systems are also presented.

The study is based on the view that emotions guide human behavior through motivational mechanisms (see [7-10]). Supporting this view, there are empirical studies in media, communications, and advertising research that showed that there is a relationship between the emotional responses to media content and form on the one hand, and the users attitude, attention, and recall on the other hand (see for examples, [11-14]). The view that motivation determines behavior is encountered also in the information systems literature, especially in the literature about the adoption of new technology, where motivation is recognized as a factor of acceptance and adoption of technology [15,16]. Frontal alpha asymmetry is an established index of approach/avoidance motivation and has been used in media research studies to examine the capability of the index to predict positive responses to adds [17] and to predict positive purchase decisions in online shopping [18]. The use of the index in reading contexts to study reading experience has not been reported so far.

An earlier version of this paper was presented at IRIS 38 (Information Systems Research Seminar in Scandinavia) Workshop, and a first revision [19] of it was accepted for presentation at HICSS-49. A second version which included an extended

data analysis was presented at MindTrek 2015; in that study [20], a preliminary video analysis resulted in an adjustment of the initial dataset by removing unreliable data, and demographics and reading profile information were included in the analysis. In this paper, we summarize the findings in [20] and provide an extensive account of the context of the study and the implications of the study methodology and findings to information systems research and design practice.

2 Context of Study

The study in this paper is part of a larger endeavor aiming at evaluating the media experience when reading on digital and traditional media, including discovering the effects of reading medium on how the reader allocates cognitive resources and processes the information. We examined two reading media: the traditional print and a tablet computer; a higher level of analysis of these two media was performed (that is, we did not divide the analysis by features of the display like size and material, by elements of presentation layout and esthetics like colors and structure, or by the navigation and user interaction actions specific to each type of medium).

To this end, we conducted an experiment in which the participants read the largest Finnish newspaper, Helsingin Sanomat, in two conditions: the traditional paper version and a digital tablet version. The experimental setting and procedures are exposed in Section 5 (for a more complete presentation, see also [19,20]). The user experience was measured by a series of measurements for different dimensions identified in a model of media experience developed for this purpose [see 21]. Using this model, three categories of data were collected: self-reports, psychophysiological measurements, and video recording. With the help of self-reports, we collected background information such as demographics, personality, reading behavior, but also the users attitudes towards and evaluations of media experience such as interactivity, usability, emotions, and attention. In addition, self-report data was collected based on the debriefing session at the end of the experiment. Psychophysiological data were collected to record emotional and cognitive responses during reading. One of these psychophysiological measurements was frontal asymmetry of cortical activity; others were electrodermal activity, facial electromyography, and heart rate. In this paper, the analysis is limited to frontal asymmetry and self-reports about demographics, reading behavior, and personality.

The theoretical model of media experience developed to conceptualize and operationalize different dimensions of media experience was based on several theories and models of emotion, cognitive processing, and user experience. The theoretical perspective relevant to the present study is that emotion guides human

behavior and it can be conceptualized based on the underlying psychological systems of approach and inhibition motivation [7-10,22]. The perspective is presented in more detail in sections 3 and 4 and forms the foundation of our study on frontal asymmetry during reading.

3 Behavioral Motivation

According to Gray [9,22], behavior and affect are influenced by two general physiological mechanisms, the so-called behavioral inhibition system (BIS) and behavioral activation system (BAS). BIS is responsible with experiencing anxiety in response to anxiety-relevant cues. It responds to novel stimuli or stimuli indicating punishment and frustrative nonreward by inhibiting behavior when negative or painful outcomes are anticipated. Thus, BIS activation causes inhibition of movement toward goals; it corresponds to a "stop" system, inhibiting the ongoing approach behavior and allowing further information processing of the environment [23]. In terms of individual differences in personality, greater BIS sensitivity is reflected in a greater inclination towards anxiety when the person is exposed to the proper situational cues (see also [23,24]).

On the other hand, according to Gray (e.g., [22]), BAS is responsible to control appetitive motivation in response to signals of reward and relief from punishment. Thus, BAS activation causes the person to move towards goals; it corresponds to a "go" system that activates ongoing approach behavior [23]. In terms of individual differences in personality, greater BAS sensitivity reflects greater inclination to engage in goal-directed efforts and to experience positive feelings when the person anticipates a reward [24].

BIS and BAS sensitivities have been used in several studies as moderator variables of behavior and affect (e.g., predicting autonomic nervous system activity [25]; predicting emotion-related effects to audio stimuli [26]). In these studies, BIS/BAS sensitivities were measured using the BIS/BAS scales developed by [24]; for a description of the scales see Section 5.4.

4 Frontal Asymmetry and Psychophysiology in Media Research

4.1 Frontal Asymmetry

In regard to the measurement of physiological processes corresponding to the two emotional-motivational systems, Davidson [27] has proposed that the left- and right-anterior brain regions are part of the underlying approach/activation and withdrawal/inhibition motivation, respectively. Relatively greater left frontal activity indicates a propensity to approach or engage towards a stimulus, whereas relatively

greater right frontal activity indicates a propensity to withdraw or disengage from a stimulus (for reviews, see [4,6,28]). EEG asymmetry over the prefrontal cortex (relative activity of the left and right hemispheres or the difference between alpha band power on the right and left anterior sites, F4/3) is an established index of approach/withdrawal motivation (see, for examples, [5]).

Frontal asymmetry is observable both during resting periods and during state-related activation [4,17]. When recorded during resting-periods, frontal asymmetry indicates a predisposition to respond to emotional stimuli and is used as an individual difference variable. During state-related activation, that is, during exposure to emotional stimuli, frontal asymmetry indicates the intensity of emotional responses. In media research, frontal EEG asymmetry during state-related activation was employed to examine the potential of advertisements to generate approach-related behavior [e.g., 17]. Recently, an experiment on predicting purchase behavior showed that higher left frontal activation during the predecision period (when seeing an image of a product) was associated with an affirmative purchase decision [18]. In the same study, it was also found that a higher perceived need for a product was associated with greater relative left frontal activation. In addition, recent research showed that frontal EEG asymmetry is higher when people are exposed to news massages about good-reputation companies as opposed to bad-reputation companies, irrespective of the news valence [29].

4.2 Psychophysiology in Media Research

Psychophysiology is a branch of psychology that studies the physiological states and changes that accompany mental and behavioral states and events [30]. Cacioppo and Tassinary [31] point out that psychophysiology studies cognitive, emotional, and behavioral phenomena by the means of analyzing the physiological principles and events. Thus, this approach equips researchers with both a conceptual perspective and a methodological toolbox to study important questions about the human processes such as cognition, emotions, and their interactions, and the interaction of people with the environment. The psychophysiological methods use non-invasive techniques to detect and measure the physiological processes in the human body [30]. For example, recordings of heart rate, electrodermal activity, facial electromyographic (EMG) activity, and brain activity are commonly employed in psychophysiological studies.

In media research, many studies have measured emotional valence (positive and negative emotions, pleasantness) during news processing using facial EMG. Typically, the activity over three facial muscle areas is observed, namely, zygomatic major (ZM; lip corner raiser), corrugator supercilii (CS; brow furrower), and orbicularis oculi (cheek raiser). Previous studies have supported the view that positive emotions are captured by ZM activation, and negative emotions by CS activation

during news reading (e.g., [32,33]). Facial EMG has been validated as an indicator of emotional valence also in other media contexts, such as listening to news, watching television, etc.; for overviews, see [11-13]). The use of facial EMG and other physiological measures during complex tasks, such as computer gaming, has also been studied (for a review, see [34]).

Motor theories of attention predict that muscle tension increases during effortful attention to external stimuli, but the exact pattern of muscles involved depend on the nature (positive, negative, simple, complex, etc.) and modality (video, audio) of the stimuli [35]. Accordingly, there is evidence that EMG amplitude of CS provides a sensitive index of exerted mental effort or cognitive load during information processing tasks [35-37]. Thus, the interpretation of high CS activity (negative affect vs. increased effortful attention) may be challenging, given that negative emotional stimuli capture more attention than positive stimuli (e.g., [36]).

Regarding attention, in media research, there are also other many ways to measure attention depending on the type of attention being studied. These methods include self-report and recording of oculomotor, cortical, and cardiac activity ([11,12,38,39]).

Though the self-report measures, when well designed and used, provide one of the most powerful methods of researching emotions, cognitive performance, and behavioral intentions, they also come with limitations. These limitations can be briefly listed as the so-called socially desirable responses, limited ability of humans to be aware of their emotions and cognitive processes, and lack of temporal precision (difficulty to remember accurately when reporting after a period of time and impossibility to study the responses to certain stimuli without interfering with the experimental task). These limitations can be overcome by using and/or complementing the investigation with psychophysiological measurements [12]. The physiological measurements are objective, specific to the purpose for which they are employed, and continuous – providing high temporal resolution which enables researchers to analyze the reactions of users to specific stimuli. Moreover, there are studies that show that not always the subjective ratings match the cognitive efforts or emotional reactions (e.g., [3]). However, the use and interpretation of psychophysiological measurements is not straightforward, and, thus, caution has to be exercised when applying them in research [40].

5 Methods

5.1 Participants

Thirty right-handed participants, recruited via email by sending invitation letters to student mailing lists, were selected for this study. Upon the experiment, the participants were instructed not to read the news in the morning of the test. The background characteristics of the participants are summarized in Table 1 (where N = 29 because one participant was omitted from analyses due to unreliable data; 28 participants were students, one participant was not a student). Background data were collected prior to the experiment: (1) via email (type of reader; because a certain degree of newspaper reading was one selection criterion); or (2) via a web-based questionnaire (all other background data). Most of the participants (90%) had reported no experience to little experience with a digital tablet or a similar gadget; thus, this sample represents rather novice users of a tablet computer. Twelve participants (40%) were at the moment of the experiment subscribed to the newspaper.

Table 1. Background characteristics of the participants, N = 29

Variable	%	**Variable**	%
Gender			
Male	34.5	**Helsingin Sanomat subscription period**	
Female	65.5		
Education level			
High school	72.4	Currently not subscribed	58.6
Professional school	3.4	One year	10.3
University bachelor degree	20.7	Two years	10.3
Master university degree	3.4	Three years	3.4
Type of reader of the Helsingin Sanomat		Four years	3.4
Regular	62.1	Five years	3.4
Occasional	37.9	More than 5 years	10.3

Variable	*Min*	*Max*	*M*	*SD*	*Median*
Age	19	40	24.24	4.15	23.00
Level of experience with iPad [a]	1	5	2.48	0.99	3.00
"I would manage well without Helsingin Sanomat" [b]	1	1	5	3.17	1.37
Reading style					
"I focus on reading with care" [b]	2	5	3.55	0.91	4.00
"I read systematically rather than browse" [b]	1	5	3.31	1.00	4.00

Note: [a] Level of experience with iPad: 1 *Not at all*, 5 *Very much*. [b] 5-point Likert scale: 1 *Strongly disagree*, 5 *Strongly agree*

5.2 Stimulus Materials and Study Design

The stimulus material was the largest newspaper in Finland, Helsingin Sanomat. Because we studied natural reading, each participant viewed a fresh issue of the newspaper, and we did not control for the contents of the news messages; 24 issues from February to beginning of April 2012 were viewed during the entire study.

The newspaper was exposed to the participants in two forms of presentation (reading media): the traditional paper and a digital version. An iPad 2 tablet, which supported a dedicated iPad application of the newspaper, was utilized as the digital platform. The informational contents (news articles, editorials, and pictures) were mostly identical on both the tablet and the print newspaper. The number of sections, number of articles per section, and number of pictures per article were identical in the two forms of presentation (occasionally, more articles on print were available). The main differences between the two forms of presentation (i.e., reading media) with respect to the function of information communication were: (1) layout (the way information was presented on a page/screen), and (2) navigation (the actions the reader had to perform in order to access the desired piece of information).

The design of the experiment was *within-subjects*. Each participant was exposed to two conditions: (1) freely browsing the print version of the newspaper of the day for 15 min, and (2) freely browsing digital news messages of the same newspaper for 15 min. The order of the conditions was counterbalanced. In both conditions, the participant browsed the same newspaper issue; thus, the informational contents (the pool of news messages) were similar; however, each individual selected for reading the news articles as he or she wished.

This design allowed us to study the participants in a natural reading situation, given the fact that the reading contents and media were exactly as they are encountered in the real life. No additional tasks were required the readers to perform.

5.3 Procedure

The experiment was administered to participants individually in a laboratory where the lightning was controlled and external light sources (e.g., sun light) could not reach the participant. The room was electrically and acoustically shielded. When a participant arrived at the laboratory, he/she was seated on a comfortable working chair at a desk and was explained the purpose of the experiment. The experimenter familiarized the participant with the data collection procedures and the questionnaires, after which the participant filled out an informed consent form. The participant was instructed how to use the tablet and to skip reading the TV program, weather information, and ads. Then the experimenter placed the electrodes for the physiological data recording. Because electrodermal activity was recorded from the

nondominant hand, the participant was instructed to use only the dominant hand for browsing. Each individual was also instructed not to move unnecessarily; nothing in the experimental setup required him/her to move.

At the outset of each experiment, the participant was left alone in the laboratory and all subsequent instructions were given on a computer screen in a Power Point presentation. The reading behavior was recorded on a video tape with a video camera for later analysis purposes.

After each reading session, the participant filled two online questionnaires implemented in Webropol (www.webropol.com) to collect self-reported media experience. Two participants filled out printed questionnaires due to technical problems with the Webropol system. All the questionnaires were administered in Finnish.

Before the first reading session, baseline resting physiological measurements were recorded. For the baseline recording, the participant was instructed to stay calm, still, to not blink unnecessarily, and to look at a fixed point on a wall in front. At the end of the experiment, the participant was debriefed and the electrodes were removed. He or she was thanked for participation and given the movie tickets.

5.4 Measuring BIS and BAS Sensitivities

Dispositional BIS and BAS sensitivities of the participants were measured before the laboratory experiment, in the same time with collecting background data. The BIS/BAS scales ([11]) were employed for this purpose. Each scale in the instrument comprises several items which are rated on a 4-point scale, ranging from 1 (*Very false for me*) to 4 (*Very true for me*). Carver and White [24] have demonstrated the convergent, discriminant, and predictive validity of the scales.

The BIS scale consists of 7 items reflecting responses to the anticipation of punishment (e.g., “Criticism or scolding hurts me quite a bit”; “I feel worried when I think I have done poorly at something important”).

The BAS scale is composed of three subscales: Drive, Fun Seeking, and Reward Responsiveness. BAS Drive consists of 4 items reflecting the persistent pursuit of desired goals (e.g., “I go out of my way to get things I want”; “If I see a chance to get something I want I move on it right away”). BAS Fun Seeking comprises 4 items reflecting both a desire for new rewards and willingness to approach a potentially rewarding event (e.g., “I crave excitement and new sensations”; “I’m always willing to try something new if I think it will be fun”). BAS Reward Responsiveness consists of 5 items reflecting positive responses to the occurrence or anticipation of reward (e.g., “When I get something I want, I feel excited and energized”; “When good things happen to me, it affects me strongly”).

For the present sample (N = 29), Cronbach's *alpha* for the BIS, Drive, Fun Seeking, and Reward Responsiveness scales were acceptable: 0.84, 0.79, 0.73, and 0.72, respectively.

5.5 Measuring Frontal Asymmetry

The physiological responses were continuously recorded during the experiment. The EEG activity was recorded using 24 Ag/AgCl scalp electrodes mounted in a stretch-Lycra cap (EASYCAP GmbH) and placed in conformity with the 10-10 system (see [5]). For the purpose of the current study, F3 and F4 scalp sites were monitored. AFz served as a ground electrode; common reference was used during the recordings. The signals were amplified using a Brainproducts QuickAmp amplifier. The software used for recording was BrainVision Recorder (Brain Products GmbH). For the EEG recording, the low cut-off filter was 0.1 Hz, and the high cut-off filter 100 Hz. EEG electrode impedances were kept below 5 kΩ.

For data preprocessing, the analysis of the raw physiological data was performed with BrainVision Analyzer v. 2.0.1. The data were filtered with 50 Hz Notch filter. The EEG data were segmented into 15 equal 1-min epochs, thus resulting 15 different values for each tuple Subject Medium Electrode-Site.

The baseline EEG was calculated for 3 min, after removing the first and last minutes of the 5-min recording. For artifact removal, all 1-min EEG segments were segmented into 0.5 s epochs, and epochs containing activity outside the range (-100 V, +100 V) were removed; thus, the segments contaminated by artifacts resulted from blinks were removed. For the remaining data, the power spectra were derived by the Fast Fourier transform (FFT) method, with a Hanning window of 10% at the end of each epoch.

Next, the physiological data values, e.g., F3 and F4, were natural logarithm-transformed. The frontal EEG asymmetry on the alpha frequency band (8-13 Hz) (henceforth denoted by FA) was calculated as Ln(F4) – Ln(F3). A similar measure was used for the baseline frontal asymmetry (baseline FA).

A preliminary video analysis revealed that some data segments were unusable, and these were removed from analysis (one subject was removed all together, and for two participants, two segments of 1-min and 6-min, respectively, were removed).

5.6 Data Analysis

To evaluate the relationships between approach/withdrawal motivation and dispositional BIS/BAS sensitivities by reading medium, we used Linear Mixed Models (LMM) procedure in SPSS. Beforehand, we performed a correlation analysis

to identify relationships between variables that may introduce multicollinearity in the LMM models; the results of this analysis were used when selecting the variables for the LMM models. We evaluated three types of models. First, we evaluated a simple LMM model without entering individual differences variables, to examine whether there are differences between the two reading media regardless of the individual differences (simple model). Second, separate models for each of the individual difference variables were created by entering them as fixed main effects and fixed interactions effects with the Medium (individual models, see Table 3). Finally, a third type of models included BIS/BAS indicators, demographics, and reading profile (multifactor profile model controlling for multicollinearity; these are not reported here because the results do not differ from the individual models).

In all models, frontal asymmetry was the dependent variable; the baseline frontal asymmetry was entered as a covariate fixed effect, and Medium, as a factor with fixed effect. The maximum likelihood method was used for the estimation of the models. A random effect of the Intercept was defined to account for the variability across Subjects; the covariance type was set to Variance Components. A repeated measure was defined by the interaction Medium Epoch, with covariance of type Diagonal (the variable Epoch indexes the 1-min segments within the reading session).

6 Results

In all models, the random intercepts across participants varied significantly ($p < 0.01$ and $p < 0.001$) confirming the large variability across participants. The fixed intercept was not found statistically significant in most of the models (except for the simple model and the individual model analyzing the effects of Focused Reading style). The baseline frontal asymmetry has shown significant effect on the frontal asymmetry in all models ($p < 0.001$). Table 3 presents the results of the LMM analysis with regard to the influence of Medium, BIS/BAS, and demographics and reading profile dimensions on the frontal asymmetry; only the individual models with significant effects are reported ($p < 0.05$).

Table 3. The influence of the independent variables on the frontal asymmetry

Independent variables [a]	LMM analysis results						
	Type III test of fixed effects			*t* test			
	df	*F*	*p*	*b*		SE_b	*95% CI*
Model 1							
Medium	(1,777.34)	17.93	.000	.15	***	.04	(.08, .23)
Drive	(1,28.58)	.00	.997	.03		.04	(-.05, .11)
Medium × Drive	(1,777.63)	21.42	.000	-.06	***	.01	(-.09, -.04)
Model 2							
Medium	(1,780.53)	5.34	.021	.10	*	.04	(.02, .19)
Fun Seeking	(1,28.59)	.46	.501	-.01		.05	(-.01, .08)
Medium × Fun Seeking	(1,780.41)	6.72	.010	-.04	**	.02	(-.07, -.01)
Model 4							
Medium	(1,773.06)	4.55	.033	.07	*	.03	(.01, .13)
Focused Reading	(1,28.64)	5.76	.023	.06	**	.02	(.02, .11)
Medium × Focused Reading	(1,772.82)	6.65	.010	-.02	**	.01	(-.04, -.01)
Model 3							
Medium	(1,777.70)	5.00	.026	.05	*	.02	(.01, .09)
Experience with iPad	(1,28.56)	0.01	.934	.01		.02	(-.03, .06)
Medium × Experience with iPad	(1,776.62)	8.81	.003	-.02	**	.01	(-.04, -.01)

Note: [a] Baseline FA is not reported; it was significant in all models at $p < 0.001$. *df* = degrees of freedom (numerator, denominator); *F* = F Score in Type III tests; *b* = estimate (for the variable Medium, calculated for Medium = Tablet); *SE* = standard error; *CI* = confidence interval (lower bound, upper bound). * $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$.

6.1 Medium

Across the participants ($N = 29$), frontal alpha asymmetry tended to be higher for print than for the tablet newspaper ($M_{paper} = 0.07$ and $M_{tablet} = 0.06$). In the simple model, the influence of Medium was not statistically significant $F(1,777.33) = 2.15$, $p = 0.14$). On the other hand, in all four reported individual models, Medium had a positive influence on the frontal asymmetry, statistically significant at $p < 0.05$ (see Table 3 for statistics corresponding to each model).

6.2 BIS/BAS

The interactions Medium × BAS Drive and Medium ×BAS Fun Seeking had a significant effect on frontal asymmetry. No main effects of BIS, Drive, Fun Seeking, and Reward Responsiveness were found statistically significant. The interaction Medium × Drive was statistically significant ($F(1,777.63) = 21.42$, $p < .001$); a higher score on BAS Drive scale was associated with higher frontal asymmetry when reading on print, and with smaller frontal asymmetry when reading on a tablet.

A similar effect was observed for the Fun Seeking score in the tablet reading condition ($F(1,780.41) = 6.72$, $p = .010$); on average, participants scoring higher on BAS Fun Seeking had a higher frontal asymmetry when reading on print, while

participants with lower scores on Fun Seeking had higher frontal asymmetry when reading on a tablet.

6.3 Reading Style

Focused Reading had a statistically significant positive effect on the frontal asymmetry ($F(1,28.64) = 5.76$, $p = .023$); one unit increase in the score of Focused Reading predicted an increase in frontal asymmetry with $b = .06$, $p = .008$). Also the interaction Medium × Focused reading was found statistically significant ($F(1,772.82) = 6.65$, $p = .010$ and $b = -.02$, $p = .01$). The study of interaction effects showed a higher frontal asymmetry when reading on print than on a tablet for subjects scoring higher on Focused Reading scale.

6.4 Demographics

Only the interaction Medium × Experience with iPad had a significant influence on the frontal asymmetry ($F(1,776.62) = 8.81$, $p = 0.003$); the estimate of the fixed interaction effect was $b = -.02$ at $p = .003$; thus, on average, the participants with higher Experience showed a higher frontal asymmetry when reading on print.

7 Discussion

In this paper, we examined whether traditional and digital reading media elicit different kind of behavioral-motivation responses as indexed by frontal EEG alpha asymmetry during newspaper reading, and whether personality or dispositional sensitivities, demographics, and reading profile have a moderating effect on behavioral-motivation responses.

We found that approach motivation indexed by frontal alpha asymmetry tended to be higher for print than for the tablet newspaper. This means that the participants felt more attracted by the print medium than by the tablet. This is in line with other studies and observations that showed reluctant self-reported attitude of users towards digital medium (e.g., [3]). However, we found that this relationship between reading medium and approach motivation responses was statistically significant only when moderated by individual characteristics (personality, reading style, and experience with a tablet computer). This indicates that individual differences have an impact on the physiological, emotional reactions to the usage digital media.

Higher Drive and Fun Seeking scores predicted higher approach motivation in the print reading condition, while lower Drive and Fun Seeking scores predicted higher approach motivation in the tablet reading condition. This means that participants with higher scores on Drive scale (persistent chasers of desired goals) or with higher scores

on Fun Seeking (people who are motivated by a desire for new rewards and potentially rewarding events) had a lower activation of left frontal cortical activity in the tablet condition than in the print condition, reflecting withdrawal motivation during reading on a tablet.

In addition, we found that people who read more focused have higher approach in the print reading condition; while less focused or careful readers had a higher approach motivation when reading on a tablet computer. Among demographics, only the experience with a tablet computer or a similar reading device revealed a significant interaction with Medium. This interaction effect was rather interesting; highly tablet-experienced participants had higher approach motivation during reading on the print medium than tablet, while novice tablet users had higher approach motivations during the reading on a tablet. The general trend shown by the average users of a tablet shows a slightly higher approach motivation towards the print than tablet. For this result, there are a few alternative explanations; (1) experienced users may use a tablet for reading in a different way than in the experiment, where they had to browse and read for 15 min the newspaper of the day; and/or (2) the design of the newspaper application was not attractive or motivating in the same way as the print newspaper. Moreover, in the sample, the experienced users of a tablet computer can be defined as early adopters of this reading device, given that at the time of the experiment in early 2012, in Finland, the percentage of people using a smartphone or tablet for reading was around 15 and 4, respectively [2]. Thus, another explanation can be related to the fact that early adopters, being a distinct group, respond differently to the use of technology than others, which can be also reflected in the lower approach motivation in the tablet reading condition.

7.1 Implications for Research

From the perspective of the methodology employed, the study showed that psychophysiological measurements are useful for identifying differences in emotional reactions during tasks involving the use of digital media (and, by extension, of any information system). However, the psychophysiological data collection has advantages over self-reports [12], but also disadvantages especially related to the specificity of the measures [30,40]. In our study, to ensure a high ecological validity of the study, we employed a limited control of the news contents and reading task. As a consequence, the confounding effect of the news contents cannot be ruled out when interpreting the findings and, thus, more in-depth analysis of the type of news messages that have been accessed and read during the reading sessions would shed light on this issue.

One limitation of the study was that we did not examine the correlation of frontal asymmetry with a self-report measure of approach/withdrawal motivation or with other measures of positive/negative affect. This aspect remains to be studied in future.

From a theoretical perspective, the study showed that emotional responses as indexed by the asymmetry observed in the frontal cortical activity differ with the reading medium and individual differences such as personality, reading style, and experience with a tablet computer.

Previous studies [25,26] have shown that personality, in particular overall BAS, BAS Drive and BAS Fun Seeking have moderating effects on self-reported pleasantness, importance, and physiological responses indexing emotional arousal and attention when the news messages are varied with respect to formal attributes such as speech-rate, background melody, or motion of talking image (when the emotional content of the news is kept constant or controlled). Thus, it was shown that not only the content of the news, but also the mode of presentation influences the people reactivity to news, and this relationship is moderated by personality characteristics. Similarly, other media studies on picture-viewing showed that the formal attributes of stimulus presentation (such as screen size and picture motion [14], color [41], image size [42], and viewing distance [43]) influence the way people experience and evaluate stimulus content. In those studies, the dependent variables were measured using self-reports or other physiological reactions (typically, facial electromyography and heart rate), and the experimental setting was more strictly controlled with respect to the variation of the stimuli. The present study has, thus, the merit of providing a high ecological validity of the result that motivation of using digital media depends on individual characteristics. Moreover, because motivation is an antecedent for behavior (e.g., usage of technology), it is possible to deduce that the existing reluctance of using digital media for reading can be due to a low motivation towards this medium, especially for people with specific individual traits.

To understand better the relationships between individual differences and approach motivation during reading on a digital medium, longitudinal studies should be conducted to analyze different segments of people (for example, by age, familiarity with different reading media) and/or same categories of people observed repeatedly over a longer period of time (to study the effect of becoming familiar with a novel digital application).

7.2 Implications for Design Practice

An implication of the findings for the design practice is that human factors such as personality traits and motivations, reading style, and level of experience with digital media should be taken into account when designing interfaces for newspaper applications and appropriate design solutions should be imagined for different user

profiles. For example, by diversifying design elements such as layout, navigation, and interaction controls as to suit different personality types, reading styles, and levels of experience with a digital platform, designers could ensure a positive user experience and engagement with the digital newspaper, similar to the experience and engagement with the traditional paper medium. This is in line with previous work [44] that highlights the need and importance of developing and using validated instruments for measuring personality traits and cognitive styles to be used in the design of information systems.

8 Conclusion

In this paper, we examined whether traditional and digital reading media elicit different kind of behavioral-motivation responses, and whether personality, reading profile, and demographics have a moderating effect on behavioral-motivation responses in this context. Behavioral motivation was measured using frontal electroencephalographic (EEG) alpha asymmetry (8-13 Hz). Personality was measured using the BIS/BAS scales.

Reading the print newspaper induced relatively greater left frontal cortical activation, suggesting higher approach motivation during reading on paper than on a tablet. The observed differences are moderated by individual differences in personality type (BIS/BAS scales), reading style, and experience with a tablet computer. BAS Drive and Fun Seeking subscales showed a significant negative effect on frontal EEG asymmetry when reading on tablet; increases in the Drive and Fun Seeking scores predicted lower approach motivation. Focused readers experienced greater approach motivation during reading the print newspaper and a higher experience with a tablet computer was not found congruent with higher approach motivation during reading on a tablet.

Thus, designers of newspaper applications should take into account also the personality and dispositional sensitivities of the potential users when working on digital newspaper interfaces. By designing and implementing suitable layout, navigation, and interaction controls as to match different personality types, reading styles, and digital media experience levels, designers could ensure a positive user experience and engagement with the digital newspaper, similar to the experience and engagement with the traditional paper medium. The study offers a possible answer to the question of why there is still “a general reluctance to accept digital reading media stem” [3]: while there is a solid familiarity with the paper medium regardless of the personality types, for certain personality types (i.e., Drive searching, Fun Seekers) the digital medium does not appear sufficiently motivational.

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