applied sciences

MDPI

Article

Not Everyone Chooses Profit (If It Is too Tiring): What Behavioral and EEG Data Tell Us

Michela Balconi [1,2], Carlotta Acconito [1,2] and Laura Angioletti [1,2,*]

1 International Research Center for Cognitive Applied Neuroscience (IrcCAN), Università Cattolica del Sacro Cuore, 20123 Milan, Italy; carlotta.acconito1@unicatt.it (C.A.)
2 Research Unit in Affective and Social Neuroscience, Department of Psychology, Università Cattolica del Sacro Cuore, 20123 Milan, Italy
* Correspondence: laura.angioletti1@unicatt.it; Tel.: +39-(0)2-7234-5929

Abstract: Background: A more rewarding choice, even if it requires more effort, is usually preferred by individuals; yet, in some cases, individuals choose less profitable and less tiring options. This study explored the behavioral and electrophysiological (EEG) correlates of healthy adults performing a task, designed to investigate the decision-making process behind the selection of more effortful (but highly monetarily rewarding) and less effortful (but less monetarily rewarding) options. Methods: A sample of 20 healthy adults (mean age = 46.40) performed the decision-making task, while behavioral data and EEG frequency bands (delta, theta, alpha, and beta) were collected. The Maximization Scale (MS) was administered to evaluate individuals' differences in the tendency to maximize their choices. Results: the results showed a general preference for selecting more compared to less effortful options, while no significant differences were obtained for the response times. Individuals who score higher on the MS High Standards subscale are more inclined to choose less effortful options; conversely, those with lower scores are more likely to choose a more effortful and rewarding option. However, no significant correlations were found between the behavioral data and the alternative search, or the decision difficulty subscales of the MS. EEG findings reported a significant interaction effect Choice × Electrode in delta, theta, alpha and beta bands. Specifically, the choice of less effortful options is associated with a higher increase in delta, theta, alpha, and beta band power in the right temporoparietal area (TP10) and by a lower activation of delta and theta in the contralateral site (TP9). The delta band decreased in left frontal area (AF7) during the task for the less versus more effortful options. Conclusions: Overall, despite more effortful and more monetarily rewarding options seeming to be the most rational ones to choose, less effortful choices are associated with specific EEG correlates, suggesting that there is a perceived advantage in avoiding automatisms, delaying gratification, and maximizing future possibilities.

Keywords: EEG frequency bands; effort; reward; boredom; delay gratification; automatism

Citation: Balconi, M.; Acconito, C.; Angioletti, L. Not Everyone Chooses Profit (If It Is too Tiring): What Behavioral and EEG Data Tell Us. *Appl. Sci.* **2024**, *14*, 4793. https://doi.org/10.3390/app14114793

Academic Editor: Alexander N. Pisarchik

Received: 9 May 2024
Revised: 27 May 2024
Accepted: 30 May 2024
Published: 1 June 2024

1. Introduction

In everyday life, depending on the type of decision and the potential reward that can be obtained, there are situations in which one decides to activate the "autopilot mode". Yet, even in the face of greater economic rewards, some people tend to avoid repetitive tasks and automatic behaviors, perhaps because they can be boring and alienating.

To fully understand if and when it is appropriate or not to use automatisms (i.e., to activate automatic responses), it may be useful to think of those situations in which more effortful behavior must be enacted to complete a given task and achieve a predetermined goal.

More effortful behavior could be defined as the result of repetition over time of the same type of behavior, which, in the long run, is then performed automatically and outside of awareness [1]. The more frequently a person repeats a given task, the easier it is to repeat and complete it, as a routine of execution is developed, and at the same time knowledge and skills about it increase. Moreover, the more often the task is repeated, the less conscious deliberation is required for its execution (which is performed non-consciously); with each repetition, therefore, nonconscious processing becomes more dominant, and task execution more routinized and automatic [1]. However, previous research studies have shown that this type of action can be linked to boredom [1,2]. Boredom could be defined as an unpleasant mental state in which one wants to do something satisfying but is unable to obtain it [3]. In this kind of situation, the term boredom refers to the state of boredom indicating a transient experience in response to a particular situation [4,5].

On the other hand, less effortful tasks encompass behaviors that require less effort and less time consumption, and could include behaviors characterized by behavioral or cognitive variety [1]. As opposed to the more effortful tasks previously described, less effortful tasks might require less effort and could be perceived as less boring.

Completing a more effortful task can be an element of personal gratification, as it increases one's sense of efficacy in one's personal and interpersonal world; in this sense, effort can increase value through the "strength of engagement" [6]. Similarly, many tasks associated with feelings of mental effort seem to have good outcomes and generate positive sensations, such as working hard yielding professional success [7]. Nonetheless, performing effortful task could also lead to boredom, while less effortful tasks have the advantage of being less physically and cost-demanding, and leave room for creativity. Therefore, it might be plausible that the decision regarding whether to engage in more or less effortful tasks also depends on the potential advantages of this choice, and on individual differences.

Based on the descriptions of more effortful and less effortful tasks, some questions arise: Do people prefer a less effortful task to a more effortful one? What are the cortical effects of choosing a more effortful vs. less effortful choice? Are there any individual characteristics associated with choosing more effortful or less effortful options?

To answer these questions, it is useful to highlight the fact that decision-making processes are strictly interrelated with human agency and reward mechanisms [8]. Indeed, decision-making can also be influenced by internal and external aspects, such as the presence of a specific type of reward (e.g., economic rewards) or the value given to the reward itself [9]. Several studies found that decisions are not only driven by the amount of the expected reward; other variables such as the probability of the reward occurring, the expenditure of energy required, and the delay to the reward are involved in the choice process [10–13]. The set of these variables has been defined as subjective "decision value" [9].

Based on the value attributed to a stimulus—which may be derived from the outcome of a decision—the motivation to select a specific choice can be defined by the processes that regulate action toward rewarding stimuli [14]. To study the role of reward in decision-making processes, several experimental tasks were developed: the Effort-Expenditure for Rewards Task (EEfRT) is an objective behavioral measure of the effort-based decision-making process [15]. It consists of a series of repeated trials in which the participant can choose between a high- or low-effort task to obtain monetary rewards of varying amounts (low-reward low-effort task and high-reward high-effort task) [15].

Despite the EEfRT representing a highly reliable and objective behavioral measure of individual differences in reward motivation, previous studies have not only collected behavioral data, but have also integrated the measurement of the neural correlates of EEfRT [16], thus highlighting the importance of an integration of these two levels of measurement. This evidence highlights how the neuroscientific perspective, which integrates the implicit brain responses with the individual's explicit and behavioral ones, has significantly contributed to the study of decision-making processes [17]. In particular, among the neuroscientific tools, the electroencephalogram (EEG) is an affordable technology for recording the brain's electrical impulses through electrodes placed on the scalp. The variations in electrical potential generated by the activity of cortical neurons are gathered in real time and with a millisecond-level temporal accuracy [18]. Moreover, the EEG is a wearable, non-invasive technique that can be used in an ecological and naturalistic non-laboratory setting [19–21].

Additionally, the EEG proves useful for providing insights into the brain's electrical activity, and allows the evaluation of the potential load and mental effort needed for decision-making processes, through the analysis of the functional meaning of the different frequency bands (delta, theta, alpha, and beta band) [16,22]. Indeed, changes in the theta band could be associated with cognitive control and the monitoring of one's actions [23], as well as in the processing of emotional responses [24]. The delta band, instead, is an index of the arousing power of the stimulus [25], but also a correlate of active cognitive processes [26] and emotion states [24,27]. The beta band, on the other hand, may be involved in the processing of cognitive effort, since an increase in frontal beta power has been proposed to reflect stress-related neural activity [28]. Finally, variations in the alpha band are associated with cognitive effort, engagement [29], and the processing of task demands [30]. Additionally, variations in the alpha band reflect task complexity and may indicate increased cortical activation as a result of mental effort [31,32]. Along with the functional significance of each band, it is also interesting to map the neural localization of EEG frequency bands' significant variations. For example, previous studies showed how the activation of left frontal activity (LFA) is related to motivation to approach or pursue reward [16,33], and that the dorsolateral prefrontal cortex (DLPFC), important for the representation and encoding of rewards, as well as the anticipation of motivationally salient events, is primarily responsible for this activity [34,35]. For instance, Hughes and colleagues [16] found that individuals with greater LFA for the alpha band at rest were more willing to expend greater effort in the pursuit of larger rewards, particularly when reward delivery was less likely.

Within this theoretical framework, the present study adopted a multi-methodological approach to explore and integrate the behavioral and EEG correlates of a novel behavioral task, created to investigate the decision-making process behind the selection of more effortful (but highly monetarily rewarding and longer-duration) and less effortful (but less monetarily rewarding and lower-duration) options. Thus, option preference depends on the interaction of two different variables: the "cost" and "benefit" associated with each option. The "cost" refers to the performance of a repetitive and automatic task for different time intervals, whereby the more effortful option costs more because it includes a greater waste of time associated with a boring task, while the less effortful option has a lower cost since it takes less time and is less tiring and boring. Instead, the "benefit" indicates the chance of gaining a higher or lower economic reward (and thus, a high or low benefit). In addition, the Maximization Scale (MS) [36,37] was administered to evaluate individuals' differences in their tendency to maximize their choices and to explore how individual characteristics in the decision-making process can be linked to the different propensities to reinforcement.

Specifically, we have hypothesized that participants prefer to choose the more effortful compared to the less effortful options, due to the presence of the higher reward (giving more weight to the "benefit" variable) associated with this kind of option. In fact, according to the literature, people display a higher attracted to rewards in similar behavioral tasks [16]. Also, it is supposed that the selection of the more effortful option, the one preferred by the participants, will be chosen more quickly compared to the less effortful options.

However, it is interesting to explore the behavioral and EEG correlates of both the more effortful and less effortful conditions, including the latter (the least popular), in which, regardless of the higher economic reward, automatic and repetitive tasks are avoided.

Focusing on the EEG correlates, we expect that the selection of less effortful options (accompanied by a lower attraction to an economic reward) can be marked by a decrease in the delta activity, since this band is an index of engaging in decision-making tasks associated with positive aspects (such as the presence of greater economic reward).

On the other hand, concerning the variable "cost", the choice of less effortful options could be determined by the decision to avoid repetitive behavior and perform tasks unconsciously and unattentively, and instead to increase the sense of being in control of one's own behavior, leading to greater activation in the theta, beta, and alpha bands, which are associated with cognitive control and the attentional process.

Finally, as regards the self-report data, we expect a potential link between individuals who prefer less effortful choices and higher scores in the MS (and especially in the MS-high standards), since it might be possible that individuals who hold high standards for themselves and things in general do not want to engage in boring and repetitive tasks (i.e., effortless choices) regardless of the expected reward.

2. Materials and Methods

2.1. Sample

A sample of 20 healthy adults was recruited through a non-probabilistic convenience sample method [N males = 11, N females = 9; Mean (M) age = 46.40; Standard Deviation (SD) age = 11.32]. To determine the minimum required sample size, we performed an a priori power analysis for repeated measures ANOVA using G*Power 3.1 software (Heinrich-Heine, Düsseldorf, Germany), and we found that a total sample size of 15 participants (with alpha error probability = 0.05 and power 0.80) was the minimum required for the detection of a significant within or between effect. By estimating a subject attrition of 15%, we added three more subjects, reaching the minimum sample size of 18 participants.

Each participant had normal or corrected-to-normal vision and was right-handed. All adults were native Italian speakers, had a minimum of 16 years of education and at least work experience. Additionally, they lived in Northern Italy. Exclusion criteria were severe physical and chronic diseases, congenital and non-congenital brain injuries, epilepsy, and neurological, psychiatric, and psychological disorders. Participants voluntarily completed written informed consent forms; they received no compensation for their time or participation in the study. The Ethics Committee of the Department of Psychology of the Catholic University of the Sacred Heart in Milan, Italy, gave its consent to this study according to the GDPR—Reg. UE 2016/679 and its ethical guidelines. The Declaration of Helsinki's guiding principles (2013) were adhered to when conducting the research.

2.2. Procedure

For the experimental procedure, which lasted approximately 10 min, the participants sat on a comfortable chair in front of a PC monitor placed about 80 cm away from their eyes in a quiet dedicated room. Each participant completed a consent form and a demographic data survey.

Next, an EEG resting state baseline of 120 s was collected before the task's execution. After receiving brief verbal instructions, participants performed the novel task while behavioral and EEG data were recorded continuously. At the end of the task, the MS was administered to collect self-report data to explore individuals' differences in the tendency to maximize their choices.

2.3. Experimental Task

The participants were required to execute a novel behavioral task, administered via a web-based experiment management platform (PsyToolkit, version 3.4.4) [38,39] and designed to study the propensity to reinforce under the condition of choosing between more effortful and less effortful tasks.

This task was composed of ten rounds, each of which required participants to choose from two different options, a more effortful or less effortful option, to obtain a specific economic reward.

The more effortful option required the subject to press the space bar for 64 trials. For the less effortful option, the participant had to press the space bar 17 trials to complete the task. The reward for the more effortful option was fixed at USD 8.00, while for the less effortful option it was EUR 4.00.

For all rounds, participants had to press the space bar repeatedly for a variable amount of time depending on the choice they made (i.e., if they selected the more effortful or less effortful option). Each press of the space bar increased the level of a virtual "bar" displayed on the screen, which highlighted where they were in the trial. Participants could win the money associated with each round if they reached the end of the virtual "bar" within the predetermined time.

Each round began with a description of a specific goal to be achieved (i.e., to fill a jug with water, water a flower until it blooms, drive a car to the finish line) and a maximum of 10 s to choose between the more effortful or less effortful option.

After the decision, participants were then shown a 1 s fixation cross, a reminder of the action to be taken to complete the task for 5 s and a "Ready" screen for 1 s. On completion of the task, or at the end of the predetermined time, a feedback information screen was shown to participants for 2 s informing them about whether they had achieved the goal of the trial. If the participant completed the trial and achieved the goal, a second feedback screen was displayed for 2 s, showing the phrase "You won" and the amount corresponding to the type of choice made (more effortful versus less effortful) for that trial (Figure 1).

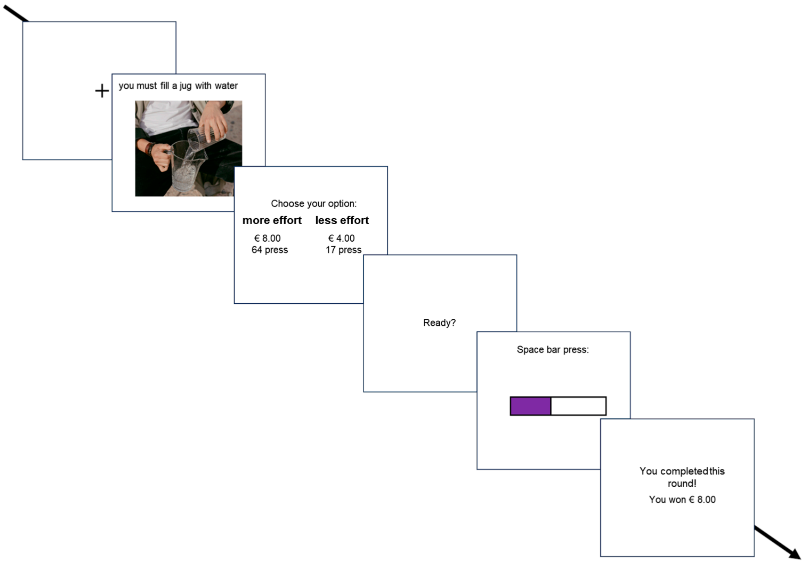

Figure 1. Experimental task flow. The figure shows a schematic representation of a single round of the task, where the more effortful option is chosen (reward obtained: EUR 8.00).

The behavioral data from each subject were collected for every single trial of each round and permitted us to explore the trends in the type of choice, the response times to make the choice (RTs), and details of the total choices, in terms of how many times the more effortful option was chosen and how many times the less effortful option was chosen. RTs, indeed, represent an indirect measure of the workload required to choose among alternatives, highlighting the cognitive cost of the decision-making process.

Prior to EEG data recording, the participants became familiarized with the overall procedure trough a familiarization session. The first four rounds were used to enable familiarization to the task and the following six rounds were considered in data analysis. The duration of this session was approximately two minutes, during which every subject was presented with four rounds with both more and less effortful options. After the familiarization phase, in which the participants experienced both the more effortful and less effort choices, the participants were asked how they perceived the task, and on a qualitative level all the participants reported that the more effortful task was more monotonous and boring, compared to the less effortful one.

2.4. Maximization Scale

The Maximization Scale (MS) is a 13-item self-report scale examining people's propensity to maximize their options, or, conversely, to choose a solution that meets their standards for sufficient quality [36,37]. A 7-point Likert-type scale is used for each item and measures the tendency of decision-makers to: (i) hold high standards for themselves and things in general (high standard subscale); (ii) search for better options (alternative search subscale); and (iii) find it difficult to decide (decision difficulty subscale).

2.5. EEG Data Acquisition and Biosignal Analysis

EEG data were collected during the resting state condition for 120 s and while performing the novel behavioral task through a wearable and non-invasive EEG recorder, the Muse™ headband (version 2; InteraXon Inc., Toronto, ON, Canada). This EEG system permits the detection of the spectral activity of each standard frequency band (delta, theta, alpha, beta and gamma) with seven dry sensors made of conductive material (silver) and silicon rubber, placed according to the international 10–20 system [40]. Specifically, of these seven electrodes, three are used as a reference and the remaining four are placed on the left and the right sides of the forehead, respectively; two in the frontal area (AF7 and AF8) and two in the temporoparietal area (TP9 and TP10). The data, sampled at 256 Hz and with a 50 Hz notch frequency filter, were detected via a system with an accelerometer, gyroscope, and pulse oximetry and through the Mind Monitor mobile application via Bluetooth. For the purpose of limiting the presence of artifacts, participants were told to keep their eye blinks and movements to a minimum. The removal of artifacts (such as eye blinks, jaw clenching, and movements) was performed after a visual inspection of all the data.

The EEG data from each electrode and each frequency band were converted in real-time into Power Spectral Density (PSD) via Fast Fourier Transformation and computed for each frequency band: delta (1–4 Hz), theta (4–8 Hz), alpha (8–13 Hz), beta (13–30 Hz), and gamma (30–44 Hz).

The variations in EEG power values during the task were computed by weighting the EEG power values during the task over the EEG power values in the baseline. For the analyses, the EEG tracing segments related to the more effortful and less effortful choices were considered.

For this study, a Muse™ headband was employed as an ecological and easy-to-use EEG wearable tool. It allows one to map the activation of the bilateral frontal and temporoparietal regions: two areas that are crucially involved in decision-making processes [41,42].

2.6. Data Analysis

First, for the behavioral data, two one-way ANOVAs were applied on the behavioral data with Choice (2: more effortful, less effortful) as the independent variable and mean scores and RTs as dependent variables.

Secondly, for EEG data, four repeated measures analyses of variance (ANOVAs) were separately applied to the dependent measure of frequency bands (delta, theta, alpha, beta). Analysis was carried out with the following factors: choice (two: more effortful, less effortful) and electrodes (four: AF7, AF8, TP9 and TP10). For all ANOVA tests, degrees of freedom were corrected by the Greenhouse–Geisser epsilon when appropriate. Simple effects for significant interactions were further checked via pairwise comparisons, and Bonferroni correction was used to reduce multiple comparison potential biases. The sizes of statistically significant effects have been estimated by computing eta squared (η^2) indices. The threshold for statistical significance was set at $\alpha = 0.05$. For the statistical analysis, IBM SPSS 29 (IBM Corp., Chicago, IL, USA) was used.

Thanks to a preliminary analysis, potential biases related to gender were checked for and excluded. No statistically significant main or interaction effects including gender were observed; this variable was thus not included in the analyses reported below.

Finally, correlational analyses were also applied between the behavioral data collected during the task and each of the subscale's scores in the MS.

3. Results

3.1. Behavioural Results

From the first ANOVA, a significant main effect of the choice factor was found [$F(1, 19) = 19{,}754$ $p \leq 0.001$, $\eta^2 = 0.510$] (Figure 2), for which higher behavioral scores were detected for the more effortful compared to the less effortful choices.

No significant differences were obtained for the RTs.

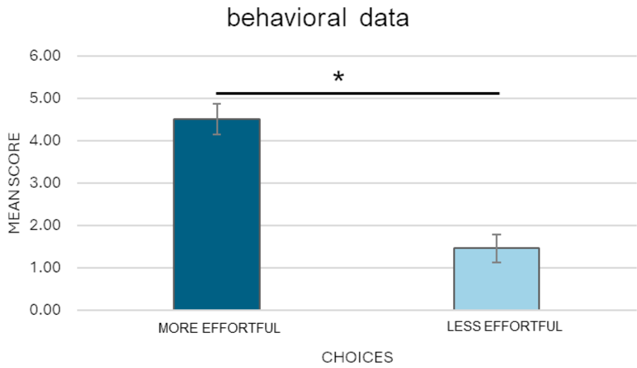

Figure 2. Behavioral data. The bar graph displays the higher behavioral scores for the selection of more effortful compared to less effortful choices on the six rounds. Bars represent the Standard Error (SE) of ±1 for all plots; asterisks (*) denote statistically significant differences with $p < 0.05$.

3.2. EEG Results

3.2.1. Delta Band

For the delta band, a significant interaction effect of choice × electrode was found [$F(3, 56) = 6.54$, $p \leq 0.01$, $\eta^2 = 0.378$]. Pairwise comparisons revealed a decrease in delta band for the less effortful compared to the more effortful choices in TP9 and in AF7. Also, an increase in the delta band was observed in TP10 for the less effortful compared to the more effortful choices (all comparisons $p \leq 0.05$) (Figure 3A). No other significant effects were found.

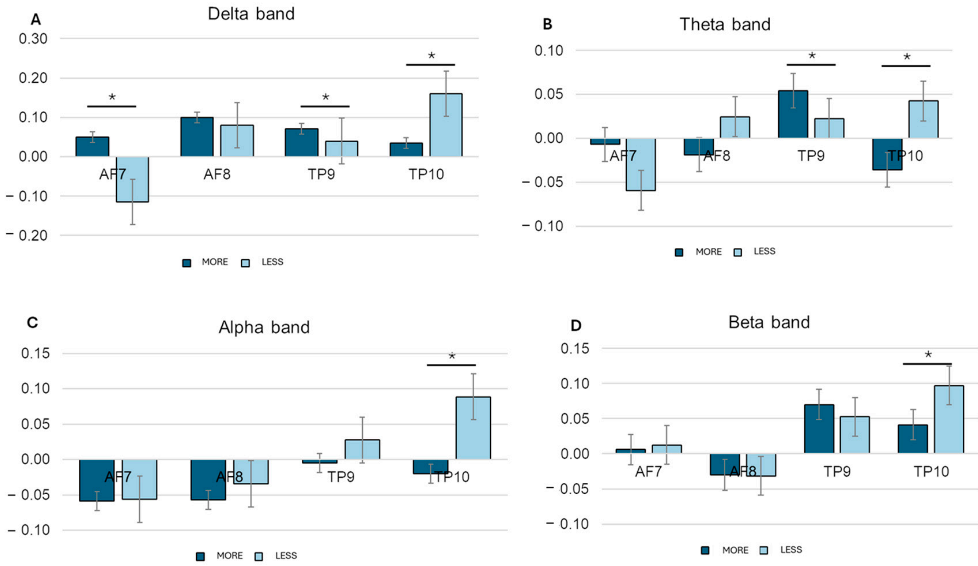

Figure 3. (**A–D**) EEG data. (**A**) The bar graph displays a decrease in delta band power in TP9 and in AF7, as well as an increase in delta band power in TP10, for the less effortful compared to the more effortful choices. (**B**) The bar chart shows a decrease in theta band power in TP9, as well as an increase in theta band power in TP10, for the less effortful compared to the more effortful choices. (**C**) The graph shows an increase in alpha band power in TP10 for the more effortful compared to the

less effortful choices. (**D**) The bar chart represents an increase in beta band power in TP10 for the less effortful compared to the more effortful choices. Bars represent the Standard Error (SE) of ±1 for all plots; asterisks (*) denote statistically significant differences with $p < 0.05$.

3.2.2. Theta Band

Regarding theta band, a significant interaction effect of choice × electrode was found [$F(3, 56) = 8.12$, $p \leq 0.01$, $\eta^2 = 0.402$]. Pairwise comparisons revealed a decrease in theta band for the less effortful compared to the more effortful choices in TP9. Conversely, an increase in theta band was observed in TP10 for the less effortful compared to the more effortful choices (all comparisons $p \leq 0.05$) (Figure 3B). No other significant effects were found.

3.2.3. Alpha Band

For the alpha band, the analysis revealed a significant interaction effect of choice × electrode [$F(3, 56) = 6.09$, $p \leq 0.01$, $\eta^2 = 0.369$]. Pairwise comparisons showed an increase in alpha band for the more effortful compared to the less effortful choices in TP10 (Figure 3C). No other significant effects were found.

3.2.4. Beta Band

Finally, a significant interaction effect of choice × electrode was observed for beta band [$F(3, 56) = 7.75$, $p \leq 0.01$, $\eta^2 = 0.398$]. Pairwise comparisons showed an increase in beta band for the less effortful compared to the more effortful choices in TP10 (Figure 3D). No other significant effects were found.

3.3. *Correlation between Behavioral Data and MS Subscales Scores*

A negative correlation was found between the more effortful choices' mean score and the MS High Standards subscale score ($r = -0.696$ $p \leq 0.001$) (Figure 4A). Also, a positive correlation was observed between the less effortful choices' mean score and the MS High Standards subscale score ($r = 0.702$ $p \leq 0.001$) (Figure 4B). No other significant correlations were observed.

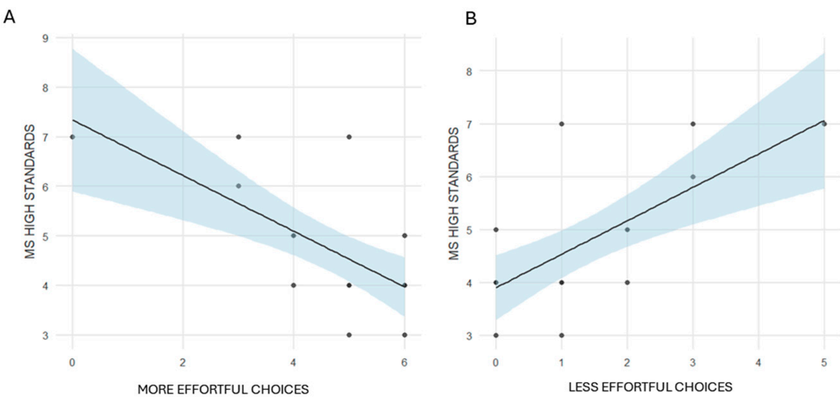

Figure 4. (**A**,**B**) Correlation between behavioral and psychometric (MS) data. The scatter plots display (**A**) a negative correlation between the more effortful choices' means score and the MS High Standards subscale, (**B**) a positive correlation was observed between the less effortful choices' mean score and the MS High Standards subscale score.

4. Discussion

The current work examined the behavioral and EEG correlates of a novel behavioral task concerning the decision between selecting more effortful (but highly rewarding) and less effortful (but less rewarding) options. The results derived from the analysis of a sample of healthy adults showed a significant tendency towards selecting more effortful options compared to less effortful ones. Interestingly, individuals who scored higher on the MS High Standards subscale were more inclined to choose less effortful options; conversely, those who scored lower on this subscale were more likely to choose a more effortful, yet more rewarding, option. Within this framework, the EEG findings suggest that the choice of a less effortful option is associated with a greater increase in delta, theta, alpha and beta band power in the right temporoparietal area, and a lower activation of the delta and theta bands in the contralateral site. Furthermore, the delta band decreased in the left frontal area during the less effortful task compared to the more effortful option. These main findings will be discussed below.

Firstly, the analysis of the behavioral data confirms our prediction and shows that participants tended to prefer the more effortful compared to the less effortful option, given the inner probability of the more effortful option to yield a higher reward. In line with the scientific literature on the EEfRT, individuals tend to display a greater willingness to expend effort for rewards [15,16]. Our results are in line with this evidence and demonstrate that this is true even though the task may be more effortful, and therefore boring and alienating. Thus, it seems that most people logically tend to choose the "most advantageous" option (with the greatest expected reward) even if "it can be boring and tiring".

Yet, our data show that even less effortful choices (options with lower monotony and reward) are selected. Indeed, as a second result, it was found that less effortful options are more commonly selected by those who tend to obtain higher scores on the High Standards subscale of the MS; and in turn, individuals who display lower scores on this MS subscale are likely to prefer a boring, even if more rewarding, task.

According to the literature, "Maximizing" means that one is willing to invest resources to find a solution that is even marginally superior to the greatest one that has been achieved so far. Specifically, high standards have been linked with perfectionism, remorse, and the desire for cognition, rather than pleasure, optimism, and life satisfaction [36]. So, the current results suggest that in the "meta-process" in which people strive to balance the decisional costs and the utility of the chosen option, individuals with higher High Standards scores seem to devalue the reward, and place greater weight on a low decisional cost (i.e., they value more highly the importance of carrying out a less boring task). Alternatively, perhaps these individuals do not feel that they do not want to carry out the more effortful task that leads to an unsatisfactory repetition (albeit with a greater gain), and are driven by wanting to minimize the possibility of getting bored (in a certain sense, at any cost). In future studies, it would be interesting to understand if an individual characteristic such as the one measured by the MS High Standards is also accompanied by a personality profile or a decision-making style that leads individuals to make less effortful choices more frequently in everyday life.

So, which implicit processes underline the selection of less effortful and apparently less advantageous choices? In this neuroscientific study, we preliminarily explored the neurophysiological (EEG) correlates associated with the choice of more effortful and less effortful options. In this way, the behavioral results showing a preference for more effortful over less effortful options can be integrated by observing another level of analysis, which deepens the neural activations related to the participants' effortful or effortless choices.

Thus, as a third interesting effect, we observed a higher activation of the delta, theta, alpha and beta bands in TP10 during the less effortful compared to more effortful choice. With reference to the localization of this significant neural effect in the right temporoparietal area, the right Temporo Parietal Junction (rTPJ) has been consistently shown to be significant when inferring and comprehending the mental states of others in several fMRI studies, highlighting its notable relevance for ToM processing [43,44]. However, the right TPJ also plays a role in other cognitive processes, and is shown to be involved in interactional mechanisms in which awareness permits the control of attention [45] and decision-making processes. Previous studies have shown that during more effortful tasks that induce boredom, levels of commission errors increase, and there is a reduction in two Event-Related Potentials (ERP, namely, P3 and error-related negativity) related to attention, suggesting an inadequate engagement of attentional resources [46]. Thus, this increase in all EEG frequency bands in the rTPJ may be due to the presence of greater awareness during less effortful choices, compared to more effortful choices, which instead involve more automatic behavioral patterns.

In addition, through the use of functional neuroimaging in conjunction with continuous theta-burst stimulation, Soutscheck and collagues (2021) showed how the rTPJ contributes to the delay of gratification and promotes the processing of future events [47]. Thus, a possible alternative explanation for this wide increase in EEG activity in rTPJ could be linked to the role of this region in delayed gratification. So, it might be that the immediate gratification for selecting less effortful options is related to not having wasted time performing a boring task and still getting a reward. Indeed, the choice of the less effortful option still provides a reward (50% lower than the more effortful choices), so it is possible to state that in this case, it is the "cost" variable rather than the "benefit" variable (i.e., reward) that weighs more.

On the other hand, a decrease in delta and theta bands was observed in the contralateral site (left TPJ, lTPJ) for the less effortful compared to the more effortful option. Theta oscillations in the prefrontal cortex were found during the stimulus-processing period [48], while delta oscillations were found in the prefrontal cortex during the decision-making period [49]. Also, the delta band is an index of the arousing power of the stimulus [25], and, under our hypothesis, we expected a decrease in this marker in relation to the expectation of a lower reward for the less effortful options. This result may appear counterintuitive; however, it must be considered that, as seen in the previous effect, the delta band increases significantly in the rTPJ for less effortful options (which include an amount of reward). Thus, it is possible to read the current result considering the increase in delta band power in rTPJ and its lower activation in lTPJ for the less effortful option. The suppression of the delta and theta bands during the less effortful options can be interpreted via consideration of the localization site, which is the lTPJ.

Further studies will have to clarify the role of low-frequency waves in posterior sites in relation to the phenomenon in question. Nonetheless, these effects confirm the presence of EEG frequency bands in brain posterior areas during the processing of reward-related options with different degrees of effort, and suggest that less effortful choices are more marked by right temporoparietal EEG activation than left.

Finally, the delta band decreased in the left PFC during the less effortful task compared to the more effortful option. In previous studies, delta oscillations in the prefrontal cortex were found to couple with beta oscillations in the premotor/motor cortex and guide decision-making [49,50]. Moreover, a former work showed that greater LFA (relative to the alpha band) was associated with increased willingness to choose the hard task and expend greater effort for a larger potential reward [16]. Perhaps in this context, the increase in delta band in the left frontal areas during more effortful tasks is a marker of the decision to engage in a task considered more rewarding, while this correlate decreases significantly for less rewarding (less effortful) options.

Overall, this study revealed a significant tendency to select more effortful options over less effortful ones in this sample of healthy participants. This behavior is closely tied to individuals' scores on the MS High Standards subscale: those with higher scores tend to choose less effortful options, while those with lower scores prefer more effortful, yet potentially more rewarding, choices.

Crucially, EEG findings unveil the neural correlates of these behavioral tendencies. When individuals choose less effortful compared to more effortful options, there is a significant increase in delta, theta, alpha, and beta band power in the right temporoparietal area, alongside a decrease in delta and theta activation in the contralateral (left) site. Additionally, delta band power decreases in the left frontal area during the less effortful task compared to the more effortful option. These EEG patterns underscore the distinct neural activities that underpin the cognitive and motivational factors driving the choice between effort levels.

The present study is not exempt from limitations. First, it would benefit from a replication with a larger sample size to increase the validity of its findings. Furthermore, in this study, there was no gender-specific hypothesis, and no gender differences were identified in our analysis. However, other research has previously highlighted gender differences in reward-based decision-making [51,52]; consequently, it is worthwhile to investigate gender-related effects in larger cohorts. At the methodological level, Muse^{TM} EEG has been proven to be a valid EEG tool for mapping phenomena related to decision-making in several ecological contexts [19–21]; however, it does not guarantee complete coverage of the scalp for EEG data collection. Future studies could replicate the present study, employing high-density EEG to explore this phenomenon more thoroughly, considering the neuroanatomical object and possible developments related to neurofunctional mapping. Also, future research could deepen the explicit self-reported reasons for choosing more effortful versus less effortful alternatives.

Finally, reward-based decisions can also depend on the decision-making style of the decision-maker, on his personality traits, on the levels of impulsivity or even on the sensitivity to reward; therefore, in future studies it will be appropriate to consider the integration of self-report scales assessing such individual characteristics.

To conclude, this research discussed the behavioral and implicit EEG correlates associated with the choice of a more effortful (but more rewarding) or a less effortful (and less rewarding) option. We were aware that the more effortful and more rewarding options seem to be the most logical choice to select, and so the current work underlines the EEG correlates of less frequently chosen, and apparently more irrational, less effortful choices, which are not selected for their rewarding value, but are more related to the tendency to want to avoid monotony and automatisms and maximize future possibilities. The current results show that one does not always choose profit if it is too tiring.

Author Contributions: M.B.: conceptualization, methodology, project administration, supervision, validation, writing—review and editing. C.A.: data curation, investigation, formal analysis, validation, writing—original draft, writing—review and editing. L.A.: conceptualization, methodology, investigation, validation, writing—original draft, writing—review and editing. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the D1—2023 funding of the Catholic University of the Sacred Heart, Milan, Italy.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki (2013) and approved by the Ethics Committee of the Department of Psychology, Catholic University of the Sacred Heart, Milan, Italy (approval code—2021 TD for thesis dissertation; approval date—1 December 2021).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author due to ethical reasons related to sensitive personal data protection (requests will be evaluated according to the GDPR—Reg. UE 2016/679 and its ethical guidelines).

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Iso-Ahola, S.E. Toward a Theory of Conscious–Nonconscious Processing and Getting Hard (and Easy) Things Done in Everyday Life. *Psychol. Conscious. Theory Res. Pract.* **2021**, *9*, 40–63. [CrossRef]
2. Seiler, J.P.H.; Dan, O.; Tüscher, O.; Loewenstein, Y.; Rumpel, S. Experienced Entropy Drives Choice Behavior in a Boring Decision-Making Task. *Sci. Rep.* **2022**, *12*, 3162. [CrossRef]
3. Eastwood, J.D.; Frischen, A.; Fenske, M.J.; Smilek, D. The Unengaged Mind: Defining Boredom in Terms of Attention. *Perspect. Psychol. Sci.* **2012**, *7*, 482–495. [CrossRef]
4. Koerth-Baker, M. Why Boredom Is Anything but Boring. *Nature* **2016**, *529*, 146–149. [CrossRef]
5. Vodanovich, S.J.; Watt, J.D. Self-Report Measures of Boredom: An Updated Review of the Literature. *J. Psychol. Interdiscip. Appl.* **2016**, *150*, 194–226. [CrossRef]
6. Higgins, E.T. Value from Hedonic Experience and Engagement. *Psychol. Rev.* **2006**, *113*, 439–460. [CrossRef]
7. Kurzban, R.; Duckworth, A.; Kable, J.W.; Myers, J. An Opportunity Cost Model of Subjective Effort and Task Performance. *Behav. Brain Sci.* **2013**, *36*, 661–679. [CrossRef]

8. Rovelli, K.; Allegretta, R.A. Framing Decision-Making: The Role of Executive Functions, Cognitive Bias and Reward. *Neuropsychol. Trends* **2023**, *33*, 37–50. [CrossRef]
9. Dixon, M.L.; Christoff, K. The Decision to Engage Cognitive Control Is Driven by Expected Reward-Value: Neural and Behavioral Evidence. *PLoS ONE* **2012**, *7*, e51637. [CrossRef]
10. Peters, J.; Büchel, C. Neural Representations of Subjective Reward Value. *Behav. Brain Res.* **2010**, *213*, 135–141. [CrossRef]
11. Wallis, J.D.; Kennerley, S.W. Heterogeneous Reward Signals in Prefrontal Cortex. *Curr. Opin. Neurobiol.* **2010**, *20*, 191–198. [CrossRef]
12. Balconi, M.; Angioletti, L. Gambling Behavior versus Moral Behavior: Methodological Perspectives in Neuroeconomic Decision-Making. *Neuropsychol. Trends* **2020**, *2020*, 5–20. [CrossRef]
13. Balconi, M.; Angioletti, L. Two Sides of the Same Medal? Reward Mechanisms between Motivational Drives and Psychopathology. *Mediterr. J. Clin. Psychol.* **2022**, *10*. [CrossRef]
14. Elliot, A.J. *Approach and Avoidance Motivation*; Psychology Press: New York, NY, USA, 2008.
15. Treadway, M.T.; Buckholtz, J.W.; Schwartzman, A.N.; Lambert, W.E.; Zald, D.H. Worth the "EEfRT"? The Effort Expenditure for Rewards Task as an Objective Measure of Motivation and Anhedonia. *PLoS ONE* **2009**, *4*, e6598. [CrossRef]
16. Hughes, D.M.; Yates, M.J.; Morton, E.E.; Smillie, L.D. Asymmetric Frontal Cortical Activity Predicts Effort Expenditure for Reward. *Soc. Cogn. Affect. Neurosci.* **2015**, *10*, 1015–1019. [CrossRef]
17. Acconito, C.; Rovelli, K.; Angioletti, L. Neuroscience for a New Concept of Decision-Making Style. *Neuropsychol. Trends* **2023**, *33*, 17–35. [CrossRef]
18. Balconi, M.; Lucchiari, C. Event-Related Potentials Related to Normal and Morphed Emotional Faces. *J. Psychol. Interdiscip. Appl.* **2005**, *139*, 176–192. [CrossRef]
19. Vanutelli, M.E.; Gatti, L.; Angioletti, L.; Balconi, M. Affective synchrony and autonomic coupling during cooperation: A hyperscanning study. *BioMed Res. Int.* **2017**, *2017*, 3104564. [CrossRef]
20. Balconi, M.; Acconito, C.; Allegretta, R.A.; Crivelli, D. What Is the Relationship between Metacognition and Mental Effort in Executive Functions? The Contribution of Neurophysiology. *Behav. Sci.* **2023**, *13*, 918. [CrossRef]
21. Balconi, M.; Falbo, L.; Brambilla, E. BIS/BAS responses to emotional cues: Self report, autonomic measure and alpha band modulation. *Personal. Individ. Differ.* **2009**, *47*, 858–863. [CrossRef]
22. Kaack, I.; Chae, J.; Shadli, S.M.; Hillman, K. Exploring Approach Motivation: Correlating Self-Report, Frontal Asymmetry, and Performance in the Effort Expenditure for Rewards Task. *Cogn. Affect. Behav. Neurosci.* **2020**, *20*, 1234–1247. [CrossRef]
23. Wang, F.; Wang, X.; Wang, F.; Gao, L.; Rao, H.; Pan, Y. Agreeableness Modulates Group Member Risky Decision-Making Behavior and Brain Activity. *Neuroimage* **2019**, *202*, 116100. [CrossRef]
24. Balconi, M.; Venturella, I.; Fronda, G.; Vanutelli, M.E. Leader-Employee Emotional "Interpersonal Tuning". An EEG Coherence Study. *Soc. Neurosci.* **2020**, *15*, 234–243. [CrossRef]
25. Harmony, T. The Functional Significance of Delta Oscillations in Cognitive Processing. *Front. Integr. Neurosci.* **2013**, *7*, 83. [CrossRef]
26. Knyazev, G.G. EEG Delta Oscillations as a Correlate of Basic Homeostatic and Motivational Processes. *Neurosci. Biobehav. Rev.* **2012**, *36*, 677–695. [CrossRef]
27. Knyazev, G.G.; Savostyanov, A.N.; Bocharov, A.V.; Dorosheva, E.A.; Tamozhnikov, S.S.; Saprigyn, A.E. Oscillatory Correlates of Moral Decision-Making: Effect of Personality. *Soc. Neurosci.* **2016**, *11*, 233–248. [CrossRef]
28. Ehrhardt, N.M.; Fietz, J.; Kopf-Beck, J.; Kappelmann, N.; Brem, A.K. Separating EEG Correlates of Stress: Cognitive Effort, Time Pressure, and Social-Evaluative Threat. *Eur. J. Neurosci.* **2022**, *55*, 2464–2473. [CrossRef]
29. Lim, S.; Yeo, M.; Yoon, G. Comparison between Concentration and Immersion Based on EEG Analysis. *Sensors* **2019**, *19*, 1669. [CrossRef]
30. Runnova, A.; Selskii, A.; Kiselev, A.; Shamionov, R.; Parsamyan, R.; Zhuravlev, M. Changes in EEG Alpha Activity during Attention Control in Patients: Association with Sleep Disorders. *J. Pers. Med.* **2021**, *11*, 601. [CrossRef] [PubMed]
31. Rietschel, J.C.; Miller, M.W.; Gentili, R.J.; Goodman, R.N.; McDonald, C.G.; Hatfield, B.D. Cerebral-Cortical Networking and Activation Increase as a Function of Cognitive-Motor Task Difficulty. *Biol. Psychol.* **2012**, *90*, 127–133. [CrossRef] [PubMed]
32. Gevins, A. Neurophysiological Measures of Working Memory and Individual Differences in Cognitive Ability and Cognitive Style. *Cereb. Cortex* **2000**, *10*, 829–839. [CrossRef] [PubMed]
33. Harmon-Jones, E.; Lueck, L.; Fearn, M.; Harmon-Jones, C. The Effect of Personal Relevance and Approach-Related Action Expectation on Relative Left Frontal Cortical Activity. *Psychol. Sci.* **2006**, *17*, 434–440. [CrossRef] [PubMed]
34. Pizzagalli, D.A.; Sherwood, R.J.; Henriques, J.B.; Davidson, R.J. Frontal Brain Asymmetry and Reward Responsiveness: A Source-Localization Study. *Psychol. Sci.* **2005**, *16*, 805–813. [CrossRef] [PubMed]
35. Herrington, J.D.; Heller, W.; Mohanty, A.; Engels, A.S.; Banich, M.T.; Webb, A.G.; Miller, G.A. Localization of Asymmetric Brain Function in Emotion and Depression. *Psychophysiology* **2010**, *47*, 442–454. [CrossRef] [PubMed]
36. Nenkov, G.Y.; Morrin, M.; Ward, A.; Schwartz, B.; Hulland, J. A Short Form of the Maximization Scale: Factor Structure, Reliability and Validity Studies. *Judgm. Decis. Mak.* **2008**, *3*, 371–388. [CrossRef]
37. Schultz, W.; Dayan, P.; Read Montague, P. A Neural Substrate of Prediction and Reward. *Neuropsychopharmacology* **1990**, *28*, 56.
38. Stoet, G. PsyToolkit: A Software Package for Programming Psychological Experiments Using Linux. *Behav. Res. Methods* **2010**, *42*, 1096–1104. [CrossRef] [PubMed]

39. Stoet, G. PsyToolkit: A Novel Web-Based Method for Running Online Questionnaires and Reaction-Time Experiments. *Teach. Psychol.* **2017**, *44*, 24–31. [CrossRef]
40. Jasper, H.H. The Ten-Twenty Electrode System of International Federation EEG. *Electroencephalogr. Clin. Neurophysiol.* **1958**, *10*, 371–375.
41. Hunt, L.T. Frontal Circuit Specialisations for Decision Making. *Eur. J. Neurosci.* **2021**, *53*, 3654–3671. [CrossRef]
42. Bitsch, F.; Berger, P.; Nagels, A.; Falkenberg, I.; Straube, B. The Role of the Right Temporo–Parietal Junction in Social Decision-Making. *Hum. Brain Mapp.* **2018**, *39*, 3072–3085. [CrossRef]
43. Saxe, R.; Kanwisher, N. People Thinking about Thinking People: The Role of the Temporo-Parietal Junction in "Theory of Mind". *Neuroimage* **2003**, *19*, 1835–1842. [CrossRef] [PubMed]
44. Saxe, R.; Wexler, A. Making Sense of Another Mind: The Role of the Right Temporo-Parietal Junction. *Neuropsychologia* **2005**, *43*, 1391–1399. [CrossRef]
45. Wilterson, A.I.; Nastase, S.A.; Bio, B.J.; Guterstam, A.; Graziano, M.S.A. Attention, Awareness, and the Right Temporoparietal Junction. *Proc. Natl. Acad. Sci. USA* **2021**, *118*, e2026099118. [CrossRef] [PubMed]
46. Yakobi, O.; Boylan, J.; Danckert, J. Behavioral and Electroencephalographic Evidence for Reduced Attentional Control and Performance Monitoring in Boredom. *Psychophysiology* **2021**, *58*, e13816. [CrossRef]
47. Soutschekid, A.; Moisa, M.; Ruff, C.C.; Tobler, P.N. The Right Temporoparietal Junction Enables Delay of Gratification by Allowing Decision Makers to Focus on Future Events. *PLoS. Biol.* **2020**, *18*, e3000800. [CrossRef] [PubMed]
48. Cavanagh, J.F.; Frank, M.J. Frontal Theta as a Mechanism for Cognitive Control. *Trends Cogn. Sci.* **2014**, *18*, 414–421. [CrossRef]
49. Riddle, J.; Vogelsang, D.A.; Hwang, K.; Cellier, D.; D'Esposito, M. Distinct Oscillatory Dynamics Underlie Different Components of Hierarchical Cognitive Control. *J. Neurosci.* **2020**, *40*, 4945–4953. [CrossRef] [PubMed]
50. Wyart, V.; de Gardelle, V.; Scholl, J.; Summerfield, C. Rhythmic Fluctuations in Evidence Accumulation during Decision Making in the Human Brain. *Neuron* **2012**, *76*, 847–858. [CrossRef]
51. Fabre, E.F.; Causse, M.; Pesciarelli, F.; Cacciari, C. Sex and the Money- How Gender Stereotypes Modulate Economic Decision-Making: An ERP Study. *Neuropsychologia* **2015**, *75*, 221–232. [CrossRef]
52. Byrne, K.A.; Worthy, D.A. Toward a Mechanistic Account of Gender Differences in Reward-Based Decision-Making. *J. Neurosci. Psychol. Econ.* **2016**, *9*, 157–168. [CrossRef]