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Event-related potentials for investigating the willingness to recycle household medical waste

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ABSTRACT

Household medical waste (HMW) recycling in the reverse supply chain has become a primary channel for infectious, toxic, or radioactive substances for environmental protection and a circular economy. Recycling managers need to understand the recycling decision-making mechanisms of households to improve the intention-behavior gap and recycling participation rate, especially in cognitive neuroscience. This study designed an event-related potential (ERPs) experiment to explore the differences in ERPs components between the willingness and unwillingness to make recycling decisions. Our findings confirmed that willingness and unwillingness to recycle can lead to a significant difference in the P300 and N400 scores. A larger P300 was evoked by willingness rather than unwillingness in the prefrontal, frontal, and frontal-temporal regions. This indicates that willingness to recycle results from a rational choice in the decision-making process. However, a larger N400 was evoked by unwillingness rather than willingness in the parietal, parietal-occipital, and occipital regions. A negative wave was evoked in households unwilling to recycle because they thought it was dangerous and unsanitary, causing a higher conflict with intrinsic cognition. The combination of HMW recycling decisions and neurology may accurately measure pro-environmental decision-making processes through brain science. Advancing the knowledge of psychological and brain mechanism activities for understanding pro-environmental choices. In turn, this can help recycling managers to accurately understand household demands for increasing the recycling intention and designing effective HMW take-back systems to solve the intention-behavior gap related to the global recycling dilemma.

1. Introduction

Since the outbreak of COVID-19, the dramatic increase in medical waste (MW) has devastated ecological systems and public health, as it exists as host for various pathogenic microorganisms [1,2]. MW in China remarkably increased from 446 ± 9 Gg/yr in 2002 to 1536 ± 34 Gg/yr in 2018 [3]. The total MW generated in Asia is approximately 16,659.48 tons/day [4]. Households and institutions are the primary sources of MW [5]. Institutions have a unique MW collection and treatment system. On the contrary, household medical waste (HMW) is disposed of along with municipal solid waste in most countries, such as China, Japan, Austria, Germany, and Nigeria. The average HMW per meter is 138.4g [6]. HMW is treated by traditional incineration or landfill, leading to secondary

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damage to wildlife and human health [7].

HMW recycling in the reverse supply chain has become the primary channel for processing MW for environmental protection and the circular economy [8]. Compared with other waste, HMW is not recommended for reuse, donation, or resale to others because of the medicine complexity, medical specificity, and strict quality requirements [9]. Moreover, HMW is classified as the most dangerous waste because it contains infectious, toxic, and radioactive substances [10]. Households play a crucial role in the MW recycling link because they decide what and how much of their consumables to recycle [11]. Although many households know about the environmental pollution caused by MW, they still purchase vast quantities of medicines, discard MW into the garbage, or flush it into a sink or toilet [7,12]. To improve household engagement in MW recycling, policymakers should determine the essential neural mechanisms influencing recycling behavior in the decision-making. Electroencephalography (EEG) differences in recycling and non-recycling behaviors are critical for designing a targeted HMW take-back system to increase the recycling rate of residents.

1.1. Household medical waste recycling

Households are the second-largest source of MW because of rising health awareness and advanced medical technology [13]. However, there are relatively few studies on HMW. Most recent studies have focused on MW management practices from the institutional perspective of healthcare, including law and policy, disinfection technology, classification criteria, information infrastructure, financial budget, disposal, and recycling practices [4,6,14]. The collection , recycling and disposal of HMW are vital to MW management practices [4]. Particularly in the post-epidemic era, establishing a well-organized and easily accessible HMW take-back system can reduce infectiousness and pollution for humans and the environment [15,16].

The existing literature on HMW recycling focuses on two aspects. One is HMW disposal and recycling practices such as purchase, use, storage, and disposal [3,17,18]. Most households report storing MW at home and throwing it away in the garbage [12]. They are aware of HMW pollution but are still accustomed to not recycling [19]. This type of HMW recycling research ignored the underlying neural driving mechanisms, leading to the intention-behavior gap in this subject. The second aspect of the current research includes factors influencing HMW recycling intention and behavior, such as attitudes, personal norms, perceived behavioral control, busyness, risk perception, knowledge, and environmental awareness [6,16,20–22]. Although these empirical findings suggest that psychological factors are vital independent variables affecting HMW recycling intention and behavior, they do not explore the relationship between neural mechanisms and HMW recycling decision-making.

In addition to the above aspects, all studies exploring HMW recycling decisions, practices, and influencing factors used traditional methods that are time-consuming, such as questionnaires, semi-structured interviews, and observation [23,24]. However, these traditional methods cannot accurately measure real-time recycling decisions. The decision-making process involves many emotions and intuitions, that traditional methods cannot measure directly [25]. Moreover, many participants may hide their true feelings, affecting the authenticity of the traditional measurement results [26]. Household recycling decisions represent a rational and emotionally dynamic process mixed with conscious awareness, that requires more accurate measurement tools.

1.2. Event-related potentials in decision research

ERPs are electrical potentials generated by brain responses and have the advantages of being non-invasive, having a cost-effective experimental design, and having higher temporal resolution [27]. ERPs help capture neural activities related to sensory and cognitive processes on the scalp, which are labeled by positive or negative amplitude, latency, and distribution areas [28]. Some scholars have attempted to measure the decision process in other pro-environmental fields using physiological and neural responses [29]. In the green marketing field, the N1, P2, and LPP components are elicited by positively framed messages at different stages of the decision-making process [30]. Various internal or external events (e.g., decisions and stimuli) cause amplitudes of diverse ERPs components in different cortical regions in decision research, including P300 and N400.

1.2.1. P300 component

The P300 component is a positive waveform that occurs around 300–500 ms following a stimulus related to decision-making, cognition, attention, or emotion. It appears to reflect the quality of the relevant assessment or decision-making processes, particularly confidence in information processing [31,32]. The P300 component shows a decreasing amplitude trend under stress conditions [33]. Increases in amplitude with decision difficulty are seen, reaching a stereotyped amplitude immediately before the response execution [34].

The role of P300 in reflecting deep thinking decision has been widely published in salient stimuli research, such as attractive words, pictures, and video [35,36]. For example [37], employed a two-alternative task in an ERPs experiment. The performance outcome evoked a larger P300 amplitude than its utility outcome in behavioral decisions [38]. investigated the effects of three personality traits on neural decision-making in an ERPs experiment. The results showed a decreased P300 amplitude with increased anxiety [39]. used a task to examine the effects of rewards on reaction decisions in an ERPs experiment. ERPs analyses indicated that the amplitude of the P300 in deceptive decision-making was higher than that in ethical decision-making.

1.2.2. N400 component

The N400 component has a negative potential for decision tasks at approximately 380–600 ms. N400 frequently appears in cognitive conflict, difficult identification, or processing too much information for semantic decision-making after visual or auditory stimulation [40]. This component also generally appears in the cognition of the conflict stage for making a purchase decision [41]. The

N400 amplitude can be considered an index of the conflict level generated by the decision-making risk, meaning that the higher the conflict level, the more negative the N400 amplitudes [42].

The existing literature reveals that N400 results from conscious mental processes in various cognitive conflict and decision-making domains [43]. For example [44], designed an experiment with three-brand classification stimuli to discover the relationship between ERPs and purchasing decisions. The results showed that N400 waves for unpurchased brands were more negative than the N400 waves for purchased brands when the brand name was not disclosed [29]. took a cognitive neuroscience approach to examine the effect of recycled water for potable use compared with recycled water for car washing on ERPs. The results showed that N400 waves for the potable use of recycled water evoked more negative ERPs than recycled water for car washing [45]. asked participants to express their moral decisions after confirming or contradicting arguments to analyze neural activities. The results indicated that the N400 amplitude of value-incongruent words was more negative than that of value-congruent words.

1.3. Research objectives

HMW recycling preserves the ecological environment and the health of wild animals and humans. However, the neural mechanisms underlying the decision to recycle HMW remain unclear. In the field of pro-environmental protection, there is a lack of research focusing on the brain mechanisms underlying recycling decision-making. In light of the above theoretical findings, ERPs are used to show the neural time course of the HMW decision-making process in response to stimuli, owing to their high temporal resolution [44,46,47]. This study aimed to answer two questions.

Question 1. What is the neural time course of the HMW decision-making process?

Question 2. Can the willingness to recycle result in a higher P300 and lower N400 amplitude of the ERPs components than the unwillingness to recycle?

We conducted an experiment to collect behavioral and EEG data from 45 participants to understand the cognitive neuroscience process involved in recycling decision-making. The experimental task asked the participants to use a computer mouse to decide whether to recycle different types of HMW as quickly as possible under specific conditions. According to decision-related studies on ERPs, the hypothesis was that the time window of the corresponding ERPs components could reflect the time course of the recycling decision-making process for HMW. Willingness to recycle was expected to elicit higher P300 and lower N400 amplitudes for ERPs components than unwillingness.

The research objectives are as follows: First, the outcomes will allow us to better understand the brain mechanisms involved in recycling decision-making. Our experimental results suggest that willingness and unwillingness to recycle can significantly differ in P300 and N400 during the 300–600 ms time course and a both conscious decisions. This can be used to judge the effectiveness of various intervention measures and improve the recycling participation rate. Second, these results advance the knowledge of psychological and brain mechanism activities to understand pro-environmental decisions. This study can provide theoretical support and ideas for innovative management research methods, help stakeholders explore household needs, and implement effective recycling management. Third, the method of exploring HMW recycling has been expanded. Instead of traditional questionnaires and interviews, our research mainly used ERPs technology to effectively measure the process of HMW recycling decisions and compensate for the subjective deviation of traditional measurements.

2. Methodology

2.1. Stimuli and apparatus

The experimental task required respondents to complete a decision task using a series of HMW decision pictures. These stimuli pictures were presented in the center of an LCD screen using E-prime 3.0 (Psychology Software Tools, Inc., Pittsburgh, PA. USA). Electrode location was determined using an expanded version of the international 10–20 electrode placement system.

2.2. Participants

G*power [48](Faul et al., 2007) was used to calculate the sample size. As previous studies show, a minimum sample size of 22 is needed to reach a large effect size ($f = 0.4$) in a two-way within-subjects ANOVA with $\alpha = 0.05$ (Type Ⅰ error) and $\beta = 0.95$ (Type Ⅱ error) [49] (Erdfelder et al., 1996). A total of 45 healthy, right-handed undergraduates (25 women and 20 men with a mean age of 19.44 $\pm$ 0.92 years) majoring in human resource management at Anhui Polytechnic University were recruited. The participants answered the following screening question: Is there medical waste in your household or dormitory? The participants had normal or corrected-to-normal vision and no history of neurological or psychiatric disorders. All participants voluntarily participated and signed an informed consent form. We deleted data with too much noise and kept the data of 42 participants (22 women and 20 men) for our final analysis.

2.3. Procedure

The participants were seated comfortably in a quiet room with soft lighting. Before the experiment, the participants were required to focus on the center of the screen from a distance of 70 cm, have a visual angle of $12.9^\circ \times 6.8^\circ$, and take a short break. When the text and pictures of a recycling scene stimulated the willingness to participate in the recycling decision, the participants responded to the stimulation as soon as possible by pressing the left mouse button; if they did not want to, they responded by pressing the right mouse button. Each picture was repeated 20 times, and the representation time of the stimuli was 6000 ms. The task paradigm for the experiment is shown in Fig. 1. The entire experiment lasted approximately 45 min, including electrode placement and instructions.

2.4. Electroencephalography recording and analysis

A total of 23 Ag/AgCl electrodes were used in the experiment (Fig. 2) and recorded using the Neuroscan ERPs system (**Neurosoft Labs Inc**). A reference electrode was placed on the left mastoid, with the midpoint of the FPZ and FZ as the ground. The standard for ERPs signal filtering, digitizing, and electrooculographic activity recording was adopted in Ref. [50]. Offline data were processed using Curry 7.0 SBA (**Neurosoft Labs Inc**). Each epoch was baseline corrected using the signal during 200 ms that preceded the onset of the stimulus. The principles of the ERPs recording and analysis were based on Sun [50].

3. Results

3.1. Behavior results

Because the ERPs signal is generally obtained after at least 20–30 trials of the same event [51], each stimulus was randomly displayed 20 times to ensure data acquisition. If the time of one is less than 20, then the data were excluded from the analysis. Participants were asked to click the left mouse button if they were willing to recycle HMW and click the right mouse button if not. Behavioral results were collected using E-Prime 3.0 and divided into two groups for comparative analysis (willingness and unwillingness), as shown in Fig. 3. The response time data were not normally distributed and might have contained outliers. The Wilcoxon signed-rank test was used to test for statistical significance. The response time was faster in the unwillingness group (1.89 ± 1.05 s) than in the willingness group (2.06 ± 1.07 s) (Wilcoxon signed-rank test, $p \leq$ 2e-16).

3.2. Electroencephalography results

We deleted the data with excessive noise from the experiment. Data from 42 participants (22 women, 20 men) aged 18–21 (mean 19.6 ± 0.8 years) were analyzed and the willingness and unwillingness trials were computed. Within-subject repeated measures ANOVAs with Greenhouse-Geisser correction were conducted to test the difference between the two conditions. The two within-subjects factors were condition (willingness vs. unwillingness) and location (regions of ERPs generated). To observe the influence of willingness to recycle HMW, we compared the mean P300 amplitudes (300–460 ms) and N400 amplitudes (380–600 ms) under two conditions using a 2 (willingness vs. unwillingness) $\times$ 4 (scalp regions) and a 2 (willingness vs. unwillingness) $\times$ 5 (scalp regions) within–subject repeated–measures ANOVAs. The grand averaged ERPs waveforms for the willingness and unwillingness to recycle

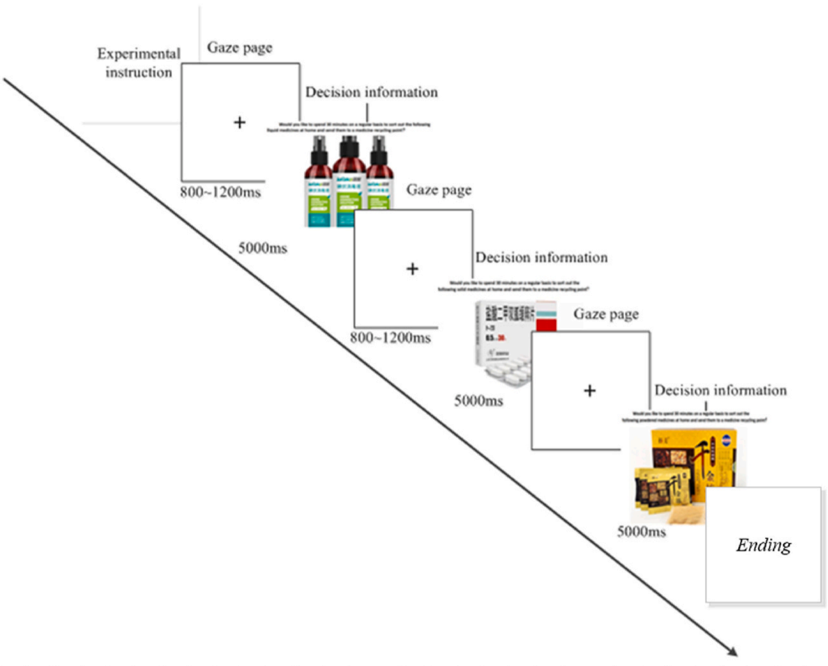

Fig. 1. Experimental procedure.

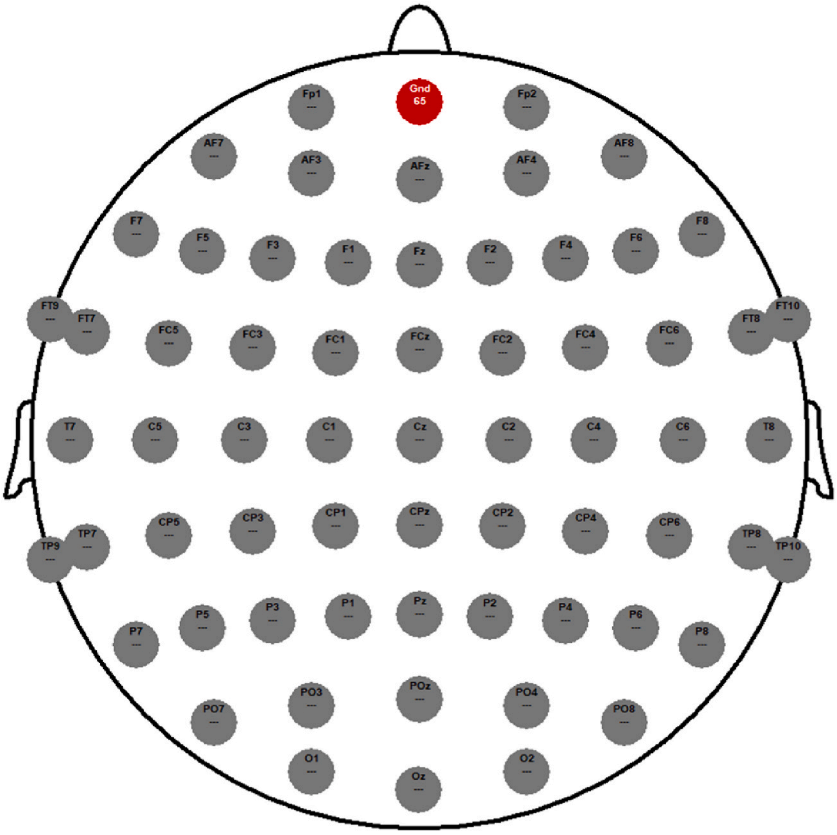

Fig. 2. Electrodes used in the experiment (23 Ag/AgCl).

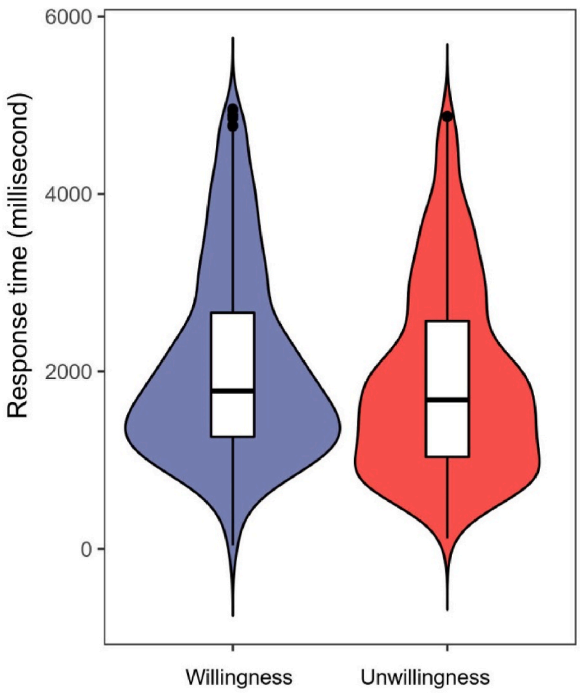

Fig. 3. Response time of the two groups.

HMW are shown in Figs. 4 and 5. Specific regions were selected for statistical analysis according to related studies [29,52], the prefrontal (AF8, AFZ), frontal (FZ), frontal–temporal (FT), frontal–central (FCZ), central (CZ), central–parietal (CPZ), parietal (PZ), parietal-occipital (POZ), and occipital (OZ) regions.

For P300, the ERPs results indicated a condition effect with $F(1, 41) = 24.600$, $p < 0.001$, partial $\eta^2 = 0.375$, and an interaction effect of willingness or unwillingness for the 300–460 ms time window with $F(1.119, 45.870) = 22.655$, $p < 0.001$, partial $\eta^2 = 0.356$. The simple effect analysis indicated that a larger P300 was elicited by willingness than unwillingness in the prefrontal ($p < 0.001$, $d = 1.258$), frontal ($p < 0.001$, $d = 2.725$), and frontal-temporal regions ($p = 0.018$, $d = 0.969$) (Table 1). A higher P300 was evoked by the stimuli, indicating the willingness to recycle HMW. Fig. 4 shows the grand average ERPs waveforms (P300) and topographic scalp distributions for the willingness and unwillingness to recycle HMW.

P300 in Fig. 4 is a positive peak with a frontal maximums at approximately 380 ms under all conditions. The reverse y-axis represents the amplitude of the P300 component and ranges from zero to more negative at the top of the chart and more positive at the bottom. The topography of the scalp showed a P300 distribution (Fig. 4). A more positive P300 is shown in Fig. 4 (i.e., blue line), which is evoked by the willingness, and below the red line for unwillingness.

For N400, the repeated-measures ANOVA results are summarized in Table 2. An interaction effect of willingness/unwillingness for the 380–600 ms time window with $F(1.143, 46.848) = 7.107$, $p < 0.001$, partial $\eta^2 = 0.148$ was present. The simple effect analysis indicated that unwillingness to recycle HMW evoked a more negative N400 than willingness. The simple effect analysis showed that a more negative N400 was elicited by unwillingness than by willingness in the parietal ($p = 0.014$, $d = -0.952$), parietal-occipital ($p = 0.033$, $d = -1.413$), and occipital regions ($p = 0.005$, $d = -1.662$). However, a more negative N400 was elicited by the willingness condition than by unwillingness in the central region ($p = 0.007$, $d = -1.625$). There was no significant difference in the central-parietal ($p = 0.381$, $d = -0.232$) region. Fig. 5 presents the grand average ERPs waveforms (N400) and topographic scalp distributions for willingness and unwillingness to recycle HMW.

The N400 in Fig. 5 shows a negative peak with central and parietal maxima at approximately 490 ms for all conditions. The topographic scalp clearly shows an N400 distribution (Fig. 5), which can arguably be considered the N400. A more negative N400 is shown in Fig. 5 (red line), evoked by the unwillingness to recycle HMW and above the blue line for willingness.

4. Discussion

Motivating households to recycle HMW and encourage environmentally friendly behavior is vital in the pro-environment field. Although some empirical studies have examined the willingness to recycle HMW, it is unclear whether and why there is a difference in the neural mechanisms of the decision-making process. This study designed an experiment to explore the differences in ERPs components between willingness and unwillingness to make recycling decisions. Our findings confirmed the original hypotheses: willingness and unwillingness to recycle led to a significant difference in P300 and N400. The results highlighted that a greater P300 was

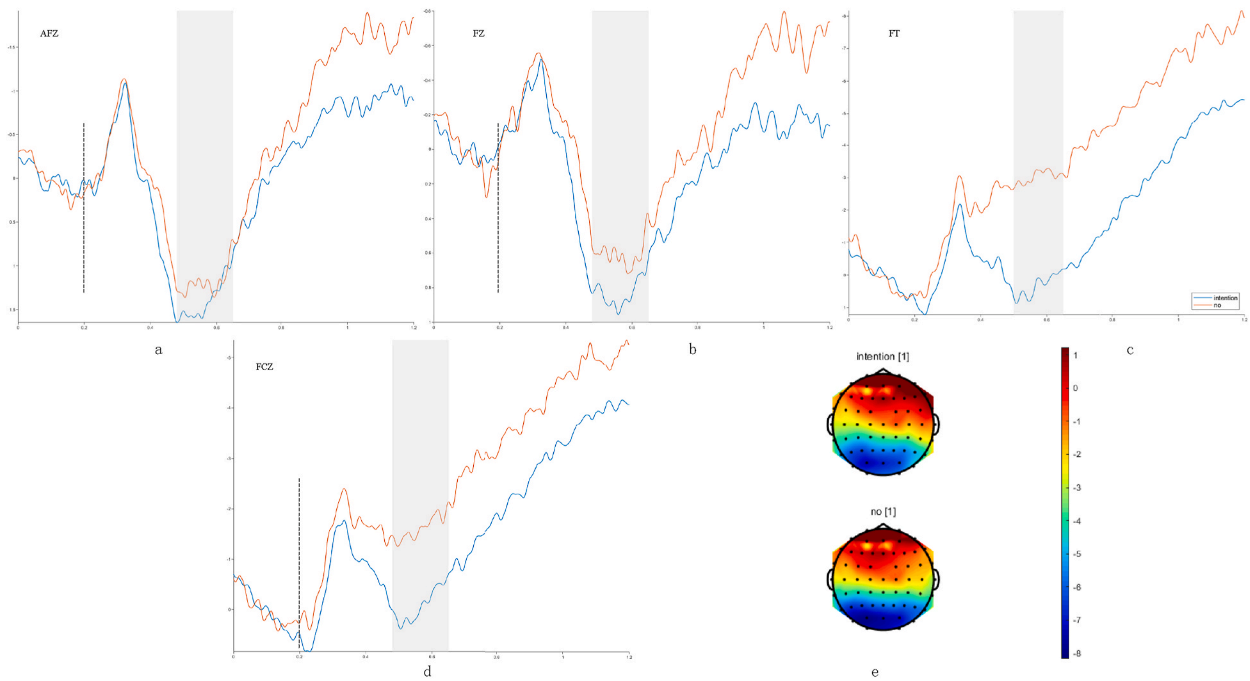

Fig. 4. a, b, c and d show the grand average event-related potential waveforms (P300) and e shows the topographic scalp distributions for willingness vs. unwillingness to recycle household medical waste at ahead-frontal, frontal, and frontal-temporal sites – Red lines: unwillingness – Blue lines: willingness.

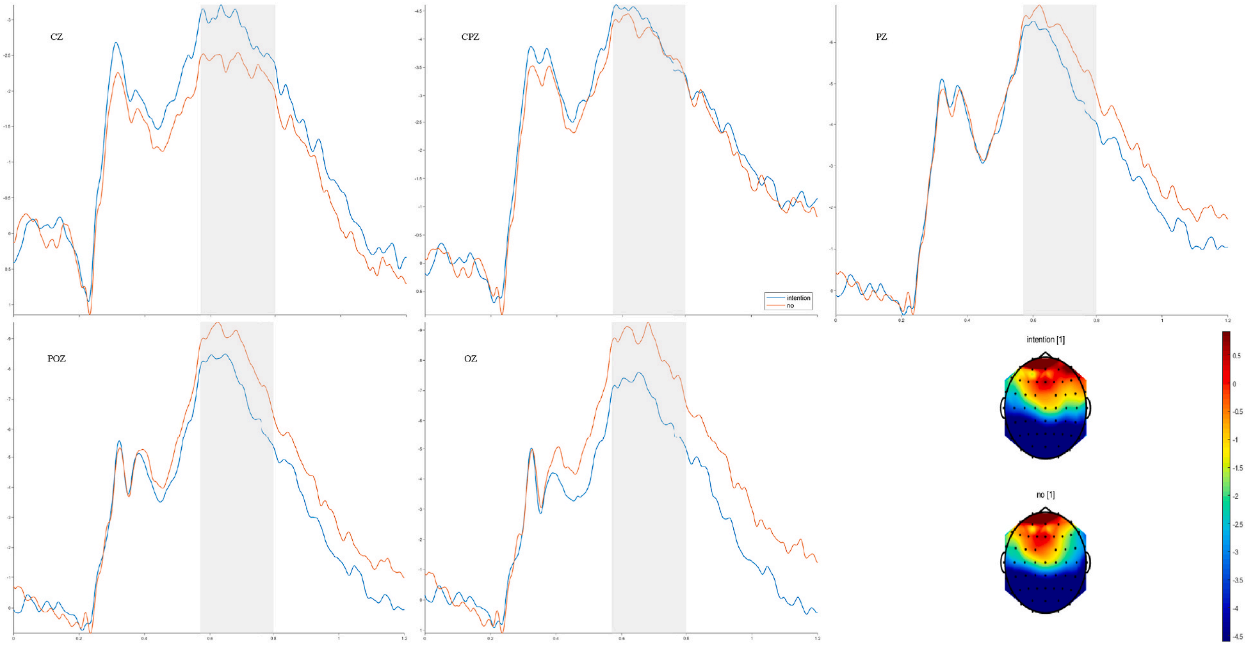

Fig. 5. Grand average event-related potential waveforms (N400) and topographic scalp distributions for willingness vs. unwillingness to recycle HMW at ahead-frontal, frontal, and frontal-temporal sites – Red lines: unwillingness – Blue lines: willingness.

Table 1
Mean amplitudes of event-related potentials and standard deviation in parentheses in the time window of 300–460 ms and the results of ANOVA in service-providing scenarios in different channels in the ahead-frontal (AFZ, AF3, and AF4), frontal (FZ, F7, and F8), and frontal-temporal (FT9 and FT10) regions of the brain.

Channel	Willingness	Unwillingness	T-value	P-value
FT	−0.512(0.311)	−3.236(0.315)	5.649	<0.001
FZ	0.927(0.331)	−0.330(0.081)	5.432	<0.001
AFZ	2.440(0.445)	1.471(0.113)	2.938	0.005

Table 2
Repeated-measures ANOVA results.

Channel	df	F	P	Partial η^2
Willingness (Y/N)	1,164	0.685	0.413	0.016
Location	1.278,46.848	76.574	<0.001	0.651
Willingness * location	1.143,46.848	7.107	0.008	0.148

evoked by willingness than by unwillingness in the prefrontal, frontal, and frontal-temporal regions. However, a larger N400 was evoked by unwillingness than by willingness in the parietal, parietal-occipital, and occipital regions. This study contributes to the literature on HMW recycling.

4.1. P300 (300–460 ms): rational evaluation to determine whether to recycle

Our study showed that a larger P300 amplitude (300–460 ms) was evoked by the willingness to recycle than the unwillingness in the prefrontal, frontal, and frontal-temporal regions. Existing literature on P300 is mainly related to the rational evaluation of the decision process, reflecting the endogenous cognitive assessment ERPs component [31,35,36,39]. The results verified that the evaluation and selection of recycling decision–making were detected late after the stimuli, and P300 was evoked at this stage. Thus, it is possible to infer whether participating in HMW recycling is a rational process. Compared with the unwillingness to recycle, the willingness to recycle resulted from a rational choice. The results indicated that the amplitude of P300 was positively correlated with the green recycling level. These results align with an ERPs study on the green purchasing decisions of consumers [53]. They discovered that the P300 component positively influences the green attitude in purchasing decisions [32,54]. Based on these studies, brain signals reflect the entire decision-making process.

P300 also reflects the confidence of an individual in the information evaluation or decision-making process [31,33,34,37,38], meaning that the quality of the information evaluation and decision-making process was high [32,54]. Some scholars believe that P300 is associated with attention allocation [55,56]. Hence, this research revealed that individuals could decide between recycling and non-recycling behavior in the 300–460 ms, invoking more attention resources. Willingness to recycle evoked a larger P300 amplitude than unwillingness, indicating that households were more concerned and confident about their willingness to recycle HMW.

4.2. N400 (380–600 ms): cognitive conflict and conscious processing generated by the recycling decision-making process between willingness and unwillingness

The results showed that the unwillingness to recycle evoked a more negative N400 (380–600 ms) than the willingness in the parietal, parietal-occipital, and occipital regions. N400 could measure the level of conflict in the decision-making process, reflecting the endogenous cognitive conflict ERPs component [40–43]. The results revealed that the cognitive conflict effect on N400 in the parietal-occipital area appeared late, approximately 380–600 ms post-stimulus. Unwillingness to recycle brought a higher conflict with intrinsic cognition and more negative N400 amplitudes than the willingness to recycle after a series of information evaluations. The results indicated that the N400 amplitude was negatively correlated with the green recycling level. This aligns with an ERPs study on green purchase behavior conducted by Ref. [57]. They found that green products elicited a lower N400 response than ordinary products. N400 can reflect cognitive conflicts and is closely related to an unwillingness to recycle.

The unwillingness to recycle that evoked N400 at 380–600 ms was also conscious processing [58]. Conscious decisions hinder recycling behavior and cause environmental pollution [20]. Thus, it is necessary to understand the formation mechanism of unwillingness to recycle. The existing literature proves that unwillingness to recycle is determined by various external and internal factors such as inconvenient service facilities, imperfect take-back systems, inadequate information publicity, and insufficient pro-environmental awareness [6,20–22]. Targeted interventions to overcome these obstacles through ERPs have become important topics for future research.

4.3. Implications and limitations

4.3.1. Theoretical implications

Our empirical findings expand research methods that combine HMW recycling decisions and neurology through brain science. The proposed method can more accurately measure pro-environmental decision processes that are difficult to survey and control using traditional methods. The traditional self-reported approach, presenting a pro-environmental decision-making model, includes a questionnaire survey, semi-structured interviews, observation, etc. [23,24]. Few studies have applied neuroscience methodologies to investigate the neural mechanisms of pro-environmental decision-making. The results of our study showed the entire process of how individuals make decisions quickly in terms of brain activity and the mind. Our study provided evidence from brain activity that the HMW recycling decision-making process happens between 300 ms and 800 ms.

These results enhance our knowledge of psychological and brain mechanisms for understanding pro-environmental decisions. HMW recycling decisions and neurology can be used to observe pro-environmental decision behavior and psychological processes through ERPs experiments, effectively revealing the time course of psychological activity in decision-making. This indicates how the willingness and unwillingness to recycle influenced P300 and N400 differently in the two courses of rapid decision-making. This research can provide strategies for governments to design effective HMW recycling management systems in line with the psychological demands of households. The study also provides theoretical support and ideas for innovative management research methods and helps stakeholders explore household' needs and carry out effective recycling management.

4.3.2. Practical implications

These experimental results verify the dynamic change process of different neural components in the brain during decision-making. This did not appear in the early stages, indicating that the HMW recycling decision is a conscious decision-making process. The HMW recycling decision includes not only the willingness to recycle rationally, but also the unwillingness to recycle with cognitive conflicts. These experimental results allowed us to better understand the brain mechanisms involved in recycling decision-making.

First, the brain mechanism of decisions can be used to judge the effectiveness of various intervention measures and improve recycling participation rate. Recycling managers can design various effective intervention schemes through questionnaires and interviews, such as the publicity of information, economic incentives, convenient infrastructure, and on-site services. The effectiveness of various intervention schemes to increase the level of recycling was tested using ERPs.

Second, it is possible to design an HMW take-back system effectively. The findings provide insights for recycling managers to understand household' demands accurately. They can also help households plan effective recycling management attributes when designing HMW take-back systems, particularly convenient services fulfilling household' requirements. HMW service providers can select appropriate services to improve the low recycling participation rates. Implementing an HMW take-back system can satisfy household demands based on the neuroscience method to solve the intention-behavior gap related to the global recycling dilemma [20,21].

4.3.3. Limitations and future directions

Some limitations and gaps may hinder the application of these results. First, this study analyzed only a sample of college students. Future research should compare these results with the EEG results of household members responsible for the disposal of HMW and identify the differences between them. Second, this study only briefly investigated the EEG differences between the willingness and unwillingness to recycle and did not test the effectiveness of various intervention programs. In the future, we can survey the effects of different HMW recycling systems on household' EEG and willingness to recycle, the influence of various incentives and punishments on household' EEG and willingness to recycle, and the effects of various information propaganda methods on household' EEG and willing to recycle. Third, this study only examined the EEG decision-making in the intention phase, and we will explore the vital influencing factors in the behavioral stage in the future.

5. Conclusions

The primary purpose of this study was to explore the differences in ERPs components between the willingness and unwillingness to recycle through a cognitive neuroscience approach. Consistent with our original hypotheses, the experimental results suggest that the willingness and unwillingness to recycle can differ significantly between P300 and N400. Willingness to recycle has a significant effect on the late endogenous P300 components during 300–460 ms. The greater amplitude of P300 was evoked by the willingness than the unwillingness to recycle in the prefrontal, frontal, and frontal-temporal regions. This study revealed that individuals could decide between recycling and non-recycling after information evaluation, invoking more attention to resources. From 380 to 600 ms, the endogenous N400 was used to measure the conflict level of the decision stimulus. Compared with the willingness to recycle HMW, the unwillingness to recycle evoked more negative N400 responses, bringing higher conflict with the original cognition in the parietal, parietal-occipital, and occipital regions. The results showed that the willingness and unwillingness to recycle were both conscious results after different cognitions and evaluations.

These results suggest that the P300 and N400 components can be used as important EEG indicators for evaluating cognitive conflict and information evaluation in decision-making. Being willing to recycle is a confident decision made by family members after a rational analysis. The unwillingness to recycle causes individual inner conflicts. This study advanced the knowledge of psychological and brain mechanism activities to understand pro-environmental decisions, helping recycling managers to accurately understand the demands of households and effectively design HMW take-back systems, namely convenient services that fulfill household needs.

Data availability statement

Data associated with this study has been deposited at https://pan.baidu.com/s/1iTlWLt0Y24S7-8CEa4yRCA?pwd=1234, and the accession number is 1234.

Ethics approval

The study protocol was approved in advance by the Institute of Neuroscience and Cognitive Psychology of Anhui Polytechnic University (No. AHPU-SEM-2023-01). All participant provided informed consent to participate in the study.

Consent to participate

All authors gave their consent to participate in the writing of the manuscript.

Consent for publication

All authors gave their consent to publish the manuscript.

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CRediT authorship contribution statement

Bin-Xiu Xu: Writing – original draft, Methodology, Data curation, Conceptualization. **Yi Ding:** Writing – review & editing, Project administration, Methodology, Funding acquisition, Data curation, Conceptualization. **Muhammad Bilal:** Writing – review & editing, Validation, Formal analysis, Data curation. **Mia Y. Wang:** Writing – review & editing, Methodology, Formal analysis, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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