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Social anxiety undermines prosocial behaviors when required effort

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ABSTRACT

Social anxiety impairs interpersonal relationships, which rely heavily on prosocial behaviors essential for healthy social interactions. The influence of social anxiety on the dynamics of helping others, through stages of prosocial choice stimulus presentation and effort, is not well understood. This study combines two experiments that integrate effort-based decision-making tasks with electroencephalography to distinguish between the choice stimulus presentation and effort phases of prosocial behavior. We examined the prosocial intention and motivation of 36 individuals with high social anxiety (HSAs) and 36 with low social anxiety (LSAs). Participants exerted effort for personal or others' gain, as well as to avoid losses. Participants chose whether to exert effort and then completed a designated number of key presses within a time limit, either to accumulate rewards or to avoid losses for themselves or others. Findings reveal that social anxiety indeed diminishes prosocial intention and effort motivation for gain. Interestingly, once HSAs decide to engage in prosocial efforts for gain, evaluative anxiety helps them reduce prosocial apathy and redirect their attentional resources from threatening stimuli to the task at hand, bringing their level of prosocial effort on par with LSAs. Moreover, HSAs exhibit prosocial apathy toward both gains and losses, with more pronounced prosocial apathy observed in loss tasks. However, evaluative anxiety does not help reduce HSAs' prosocial apathy in loss tasks. Notably, when striving to avoid losses for others, even without evaluative anxiety, HSAs demonstrated prosocial behavior indistinguishable from that of LSAs, suggesting that the goal of avoiding loss promotes prosociality among HSAs. Overall, while social anxiety diminishes individual prosocial behavior, evaluative anxiety and sensitive action goals can mitigate its impact to some extent. These findings are critical for developing strategies to enhance psychological health and promote healthier social interactions.

Introduction

Social anxiety is characterized by the fear of being in social or performance situations that involve potential negative evaluation or scrutiny from others (Kasper, 1998; Morrison & Heimberg, 2013). Research consistently shows that social anxiety impairs interpersonal relationships (Aderka et al., 2012; Alden & Taylor, 2004, 2010). For instance, individuals with high social anxiety (HSAs) often experience poorer quality friendships (Rodebaugh, 2009) and are at a higher risk of lacking intimate friends (Davidson et al., 1994). Prosocial behavior involves actions that benefit others, often requiring effort, financial cost, or enduring discomfort (Contreras-Huerta et al., 2022; Lockwood et al., 2022), is central to healthy social relationships and is a key promoter of friendship and familial bonds (De Waal, 2008; Fehr & Camerer, 2007; Fehr & Fischbacher, 2003). However, the frequency and degree to which these behaviors are exhibited can differ among individuals and appear to be disrupted by various mental health issues, including anxiety and depression (Gilbert, 2015; Robson et al., 2020). Although much empirical research has focused on healthy populations' intention to engage in prosocial actions (prosocial intention) and the efforts expended (prosocial effort) in such behaviors (Lockwood et al., 2021, 2017, 2022), little is known about the specific characteristics and neural mechanisms of prosocial intention and effort in individuals with social anxiety. Consequently, there is a dearth of empirical studies investigating how

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levels of social anxiety affect prosocial intention and effort both behaviorally and neurologically.

Do HSAs exhibit different prosocial behaviors compared to individuals with low social anxiety (LSAs)? Surveys using questionnaires with college students have found that higher levels of social anxiety are negatively associated with prosocial behaviors (Li & Li, 2023). Consistently, HSAs report lower willingness to volunteer, and even when they do participate in volunteer activities, they contribute fewer hours of service (Handy & Cnaan, 2007). Experimental findings further support this pattern: in the prisoner's dilemma game, HSAs exhibit significantly less generosity compared to LSAs (Rodebaugh et al., 2016). Similar results emerge from economic trust games, where socially anxious individuals show reduced cooperative intent relative to healthy controls (Sripada et al., 2013). This phenomenon can be explained by the motivational concerns theory of social anxiety. According to this theory, HSAs experience heightened anxiety about being evaluated by others, which primarily drives them to avoid situations where they might receive negative social evaluations (Arkin et al., 1986; Schlenker & Leary, 1982). These individuals typically engage in self-protective behaviors to achieve this goal, often adopting cautious and risk-averse behaviors to carefully avoid any situations that might lead to negative evaluations (Meleshko & Alden, 1993). However, prosocial behaviors can involve aspects of self-performance and the potential for social evaluation of such performances. As a result, HSAs are particularly conservative and tend to avoid prosocial behaviors to minimize the risk of negative evaluations. Prosocial behavior is commonly assessed through standardized, controlled economic social decision-making tasks such as the dictator game, simulated charitable donation tasks, and the ultimatum game (Carter, 2012; Kishida et al., 2010; Sharp et al., 2012). Studies utilizing these paradigms suggest that HSAs engage in fewer prosocial behaviors in these games compared to those with LSAs (Rodebaugh et al., 2016, 2013). However, the reliance on economic decision-making tasks in these studies may obscure true variations in social motivation and confound underlying mechanisms. Firstly, the personal costs involved in these tasks are always financial. Yet, many everyday prosocial behaviors do not incur economic costs to the individual. Furthermore, in tasks like the dictator game and the ultimatum game, giving more money to others equates to giving less to oneself, which confounds the distinction between self-preference and other-preference. Therefore, by clarifying motivation directed towards self and others and examining prosocial behaviors that involve non-financial costs, we can more comprehensively and objectively assess whether social anxiety impacts an individual's prosociality.

One key factor influencing prosocial behavior is the effort cost involved; however, people often show reluctance to exert effort (Contreras-Huerta et al., 2022). Many prosocial behaviors require exert effort, yet this aspect has been underexplored. Whether assisting someone with a physical task or helping a friend make progress, these actions necessitate a prosocial motivation—willingness to exert effort for the benefit of others. Importantly, previous research posits that effort involves two critical components (Manohar et al., 2015): first, the decision of whether to exert effort (effort intention), and second, the motivation to drive actions (effort level) towards a desired outcome. Previous studies have demonstrated that healthy individuals generally tend to be less inclined to initiate highly effortful actions that benefit others than those that benefit themselves. Even when they do decide to help others, they are not as motivated to put in effort for the benefit of others as they are for their own. These phenomena are termed prosocial apathy (Lockwood et al., 2017). Given that HSAs generally avoid and are indifferent to social interactions, it raises the question whether they also exhibit prosocial apathy. **Therefore, we propose hypothesis 1: HSAs, like LSAs, exhibit prosocial apathy, prioritizing self-benefit over the benefits of others with a stronger motivation for personal benefit.**

Additionally, previous research on the prosocial behavior of individuals with social anxiety has primarily used economic decision-making paradigms, which generally require only the execution of a prosocial decision to successfully help others. However, in real life, after making a prosocial decision (prosocial willingness), there is an ongoing process of attempting to help others, where our actions may or may not successfully aid others. This success rate largely depends on our self-performance (prosocial effort), which can lead to potential or actual evaluations by others, thereby causing evaluative anxiety among the prosocial actors (Klein & Epley, 2014). Therefore, a physical-effort-based decision-making paradigm has recently been designed to explore both the decision-making and effort phases of prosocial behavior (Lockwood et al., 2021, 2017). In our physical-effort-based decision-making paradigm, participants are asked to choose between higher effort (30 %−90 % of the maximum number of consecutive key presses within 5 s) corresponding to higher rewards (30–90 cents) and baseline effort (0 % of the maximum number of consecutive key presses) corresponding to lower rewards (10 cents). Once the effort choice is made, participants must complete a specified number of effort tasks within a given time frame to earn rewards for themselves or others. This paradigm effectively distinguishes between the decision and effort phases of prosocial behavior. In addition, existing studies have shown that prosocial behavior is influenced by whether the context is public or private. For instance, research involving healthy participants found that the presence of an audience enhances prosocial levels (Kurzban et al., 2007; Piazza & Bering, 2008), while the absence of an audience diminishes them (Haley & Fessler, 2005). When deciding to act prosocially, and in the execution of prosocial behavior, we may find ourselves in either a public (the presence of an audience) or private contexts (the absence of an audience). Individuals with social anxiety are particularly fearful of others' evaluations, which may lead to increased anxiety and indifference, thereby diminishing their motivation and goal-directed behaviors (Rodebaugh et al., 2013). Accordingly, our study investigates how different contexts—public with potential evaluation and private without evaluation—affect prosocial decision-making and performance in effort-based tasks among individuals with varying levels of social anxiety. **Thus, we propose hypothesis 2: Compared to LSAs, HSAs are less willing to engage in effort-based prosocial behavior in public context but show no significant difference in private context.**

The millisecond temporal precision of electroencephalography (EEG) allows for the exploration of the temporal dynamics of prosocial behavior through effort-based decision tasks, including an analysis of brain responses induced during the choice stimulus presentation and effort phases. Extensive research on decision-making has focused on the P3 component, which is associated with motivation, evaluative processes, and decision-making processes (Bowyer et al., 2021; Nieuwenhuis et al., 2005; Yau et al., 2021). Research has shown that larger P3 amplitudes positively correlate with individuals' decision preferences (Guo et al., 2016; Lin et al., 2018) and are evident in decision-making scenarios involving rewards (San Martín, 2012). Specifically, stronger preferences and higher reward magnitudes evoke larger P3 amplitudes (Parvaz et al., 2007). Based on this, **we propose hypothesis 3: During the choice stimulus presentation phase, there will be no significant difference in P3 amplitudes between HSAs and LSAs when the choice stimulus is presented in a private context. However, in a public context, the anxiety and fear of evaluation may make HSAs less willing to choose to work for the benefit of others. Consequently, during the choice stimulus presentation phase, HSAs will exhibit significantly lower P3 amplitudes compared to LSAs.**

During the effort phase, we focus on the early P1 and P2 components, as well as the late P3 components. Previous research suggests that the P1 reflects the automatic attraction of visual spatial attention (Di Russo & Spinelli, 1999), being highly sensitive to the allocation of attention—the greater the attention allocated to stimuli, the larger the P1 amplitude, making it a direct measure of attention allocation (Liu et al., 2024). The P2 amplitude reflects the complexity involved in assessing emotional and motivational content (Rossignol et al., 2012; Zougkou et al., 2017). Therefore, an increase in P2 amplitude, which is also associated with the evaluation of threat stimuli (Bar-Haim et al., 2005; Eldar et al., 2010), may indicate greater attentional focus by socially anxious individuals toward motivationally significant stimuli, such as self-performance and self-relevant interests. Based on this, **we propose hypothesis 4: In private contexts, when making efforts for the benefit of others, there is no significant difference in P1 and P2 amplitude between HSAs and LSAs. However, in public contexts, when making efforts for the benefit of others, HSAs fear negative evaluation from others, leading them to particularly focus on their performance during the effort phase. Consequently, the P1 and P2 amplitudes generated by HSAs are significantly larger than those of LSAs.** The P3 is responsive to task relevance, arousal level, motivational significance, and the impact of these factors on cognitive resource allocation, showing more strategic processes among later components (MacNamara et al., 2009; Olofsson et al., 2008). Therefore, **we propose hypothesis 5: In the late stages of the task, HSAs strategically recognize the need to shift their attention from self-performance-related stimuli to the task itself. As a result, when making efforts for the benefit of others in public contexts, their visual P3 amplitude is significantly lower than that of LSAs.**

To investigate how HSAs actively pursue benefits for themselves and others, and whether situational contexts influence their prosocial behavior choices and performance, we conducted a study with two groups of adults—one with high social anxiety (HSA) and another with low social anxiety (LSA). They were tested in an effort-based reward decision task, referred to as experiment 1. Previous research has shown that people are more sensitive to losses than to gains, leading to increased motivation in effort-based tasks aimed at avoiding losses rather than securing rewards (Tversky & Kahneman, 1991, 1992). Thus, in experiment 2, we employed an effort-based loss avoidance task. This was designed to replicate some findings from experiment 1 and to test whether prosociality can be enhanced by altering the goals of prosocial behavior. Experiment 2 allowed us to explore two key questions: (1) Do HSAs exhibit a loss aversion effect that leads to more prosocial decisions? (2) When avoiding losses, are HSAs more willing to exert higher levels of prosocial effort?

Methods

Experiment 1

Participants

We recruited 837 university students from Zunyi Medical University (Zunyi, China) to complete the Chinese version of the Liebowitz Social Anxiety Scale (LSAS) (He & Zhang, 2004; Safren et al., 1999). The original version of the LSAS scale was developed by Liebowitz and is a self-assessment tool consisting of 24 items. Each item has two scoring dimensions: the anxiety and fear emotional responses elicited by the described situation, and the avoidance response to the situation. The total score of the LSAS can be obtained by summing the scores from both dimensions for each item. The Chinese version of this scale demonstrated adequate internal consistency, with a coefficient of 0.90, and test-retest reliability of 0.91. By integrating the scoring standards of the Chinese version of the LSAS (with 38 points being the critical threshold for determining social anxiety) (Rong et al., 2007) and the relative scores of the participants, we categorized subjects based on the top and bottom 15 % cutoff points, resulting in a high score group threshold of 64 and a low score group threshold of 39. Considering both criteria, we set the cutoff point for the HSA group at 64 and for the LSA group at 38, subsequently selecting 73 participants, all of whom were right-handed. Participants scoring $<$38 on the LSAS were categorized into the LSA group (36 individuals; 17 females; average age: 19.75 ± 1.08 years), and those scoring 64 or above were classified into the HSA group (37 individuals; 19 females; average age: 19.92 ± 0.8 years). Before the experiment, the Chinese version of the Patient Health Questionnaire-9 (PHQ-9) (Wang et al., 2014) was used to evaluate the depression levels of 73 participants. Among them, 72 scored 14 or lower, indicating an absence of severe depression in these individuals. However, one participant from the HSA group scored 16, which signifies severe depression (scores above 15 indicate severe depression) (Sun et al., 2022). As a result, this individual was excluded from the final data analysis. Therefore, the analysis of behavioral and EEG data was carried out on the remaining 72 participants. Additionally, all participants' both hands were free of injury or impairment and had normal or corrected-to-normal vision, no color vision deficiencies, no harmful drinking habits, no history of drug or substance misuse or dependence, and no current or past neuropsychiatric disorders. All participants read and signed an informed consent form before participating in the experiment and were compensated with either a monetary reward or credits upon completion. The study was approved by the Ethics Committee of Southwest University, with the approved ethics number: H24122.

Design

In the reward experiment, participants completed two blocks: one in a public context and the other in a private context, with each block consisting of 80 trials, totaling 160 trials. Within each block, half the trials required participants to exert effort for personal gain (the 'self-gain' condition), while the other half required effort for the benefit of the receiver (the 'other-gain' condition). The sequence of the blocks was counterbalanced among participants using a Latin square design to minimize order effects. To prevent fatigue, participants were given a 10-minute rest after each block. Each trial required participants to choose between a baseline option, which involved no effort and offered a reward of 10 cents (referred to as the rest option), and an effort option, which demanded varying levels of effort (30 %, 50 %, 70 %, and 90 % of the maximum number of consecutive key presses within 5 s) corresponding to increasing monetary rewards (30, 50, 70, and 90 cents). Each effort level consisted of 40 trials, with higher effort levels corresponding to greater monetary rewards.

Apparatus

Experimental stimuli were presented using E-Prime 3.0 software, which also recorded behavioral data. HP wired headsets delivered private auditory cues, while HP wired speakers broadcast cues in public contexts. Participants responded using a standard keyboard, and the computer screen displayed real-time visual feedback on key press progress.

Procedure

Role-assignment procedure. Experiment 1 began with the allocation of roles. To ensure participants believed their choices impacted another person, they were informed that they had been paired with a second participant, who was a confederate (played by a member of the research team: a 21-year-old female member for female participants and a 20-year-old male member for male participants). Upon arrival at the laboratory, the real participant and the confederate were seated in separate rooms, divided by a wall and door, to prevent any visual contact, a procedure similar to that used in research by Crockett et al. (Crockett et al., 2014). The experimenter, stationed at the door between the two rooms, instructed them to remain silent and attentive. The participants were assigned roles through a random draw of colored balls: red balls designated the role of an operator in the reward task, while blue balls identified the confederate as a passive receiver. The tasks involved various decisions and levels of effort, where operators could earn money either for themselves or the receiver. The earned money, along with a participation fee, will be distributed to them at the end of the experiment.

Before the draw, both participants are given an identical white glove and instructed to wear it on their right hand. The experimenter then flips a coin to decide who draws from the box first. Each participant remains seated in their original position, holding the ball they drew with their gloved right hand. They extend their arm forward towards the door to present the ball to the other participant. This gesture ensures that each participant can see the other's drawn ball, yet without being able to discern each other's physical appearance. To enhance realism, the experimenter collects the WeChat payment QR code from the participant who drew the blue ball, ensuring both participants can observe this action. At the end of the experiment, the experimenter transfers all the money won to the operator's WeChat account. The operator then transfers the money earned for the receiver by scanning a WeChat QR code. This process is supervised and facilitated by the experimenter. Finally, the experimenter audibly informs the participant with the blue ball that they are scheduled for a memory task in a separate laboratory, ensuring the real participant hears this part of the procedure. Additionally, the experimenter reiterates to both the operator and the receiver that they will have no further contact during or after the experiment. The receiver (confederate) is then led out of the room by another experimenter, leaving the real participant to proceed with the reward task.

Task procedure. Initially, we measured the maximum number of consecutive key presses (MNoCKP) of the 'Q' key on a standard keyboard using the pinky finger of the participants' non-dominant hand (left hand) within a 5-second interval to establish a baseline for effort levels. This approach accounted for individual differences in pressing speed, ensuring that the effort levels assessed in the study corresponded directly to these variations. Participants were instructed to repeat the test to capture the MNoCKP within 5 s five times. They were informed that monetary rewards would be based on the average number of presses across these trials, with higher averages yielding larger rewards. After determining each participant's individual threshold to control for potential baseline differences in MNoCKP, we assessed whether the initial effort exerted differed significantly between groups. Statistical analysis revealed no significant differences in maximum thresholds between the LSA and HSA groups ($t(70) = 1.15$, $p = 0.253$, Cohen's $d = 0.13$, independent-sample *t-test*). Furthermore, we measured maximum thresholds before providing participants with any instructions about the experimental tasks to prevent influence on their performance.

The experimental setups for private and public contexts are as follows: In the private context, participants alone in a laboratory room, wore headphones to receive auditory feedback for each trial. The feedback consisted of auditory cues: a success sound played after a successful key press when effort was exerted; a failure sound if the effort failed; and a rest sound if the participant chose to rest. This setup aimed to create a private, non-evaluative environment. In the public context, without headphones, the same auditory cues were broadcast through the room's speakers during the feedback phase. Additionally, two observers (designated as two members of the research team), a male (21 years old) and a female (22 years old), wore white masks to avoid interference from external appearances. They entered the participant's room through the door behind the participant's left side. The participant was seated in front of a screen displaying stimuli while wearing an EEG device with conductive paste applied. The two observers quietly sat 1.5 m behind the participant. Subsequently, the experimenter, in a voice loud enough for the participant to hear, instructed the observers to silently record the counts of 'success', 'failure', and 'rest' events, as indicated by auditory cues, using paper and pen, thus creating a publicly evaluated environment. Finally, the experimenter informed the participants that they only needed to follow the instructions and prompts displayed on the computer screen to complete their own task and that they did not need to pay attention to anything else.

In this study, participants were tasked with making decisions regarding their willingness and the extent of effort they were prepared to exert to earn real monetary rewards, either for themselves or for another participant randomly assigned by drawing a blue ball (referred to as the 'receiver'). Each trial offered a choice between a 'work' option, with effort levels varying at 30 %, 50 %, 70 %, and 90 % of their MNoCKP within 5 s, corresponding to rewards of 30, 50, 70, and 90 cents respectively, and a 'rest' option, which required no effort and offered a fixed reward of 10 cents. Participants were informed that the earnings from 'receiver trials' would be allocated to the receiver, with assurances that their identities would remain anonymous, and that the receiver would not know the bonus was the result of another participant's effort.

Each trial commenced with a white fixation cross displayed for 800 ms, followed by a screen indicating the trial type (red for self, blue for receiver) for 1000 ms, and then a blank screen period lasting from 500 to 800 ms. Subsequently, participants reached a decision screen where choices were made using the left or right arrow keys with their right hand on a standard keyboard (Fig. 1**A**). This interface was configured to advance automatically upon a keypress. Following this, the chosen option was then highlighted with a green box for 500 ms, succeeded by another blank screen interval of 500 to 800 ms. Selecting the work option triggered the appearance of an empty bar on the screen. To earn the displayed reward, participants were required to press the 'Q' key the specified number of times within a maximum duration of 5000 ms. As participants pressed the key, the empty bar progressively filled with color (red for self, blue for receiver). If participants completed the required number of presses in less than or exactly 5000 ms, the bar would become fully filled, and the interface would then advance to a blank screen for 500 to 800 ms. Then, a screen would emerge for 1000 ms, displaying the amount of monetary reward earned, along with a short auditory 'success' signal. Failure to achieve the necessary key presses within this period resulted in a display showing zero earnings, after a blank screen for 500 to 800 ms, along with a 'failure' auditory cue. Opting for the rest option displayed a colored bar (red for self, blue for receiver), which required no action and remained onscreen for a random duration between 2000 and 5000 ms. This variable timing was implemented to accommodate the immediate transition of the effort task interface upon completion of the required key presses within five seconds, which naturally resulted in variable presentation times.

Experiment 2

Participants

The participants in Experiment 2 were the same as those in Experiment 1, totaling 72 individuals. This included a low social anxiety (LSA) group of 36 individuals (17 females, average age: 19.75 ± 1.08 years) and a high social anxiety (HSA) group of 36 individuals (19 females, average age: 19.89 ± 0.78 years). Prior to the experiment, all individuals signed an informed consent form. Upon completion of the study, participants were compensated monetarily. The study was granted approval by the Ethics Committee of Southwest University, under the approval number: H24122.

Design and procedure

The study's design and procedure were largely consistent with those of experiment 1 but included three notable modifications (Fig. 1**B**). First, the new task aimed at avoiding cents losses. Second, in the loss-avoidance task, each trial offered a choice between a 'work' option and a 'rest' option. The 'work' option required varying levels of effort, at 30 %, 50 %, 70 %, and 90 % of the participant's MNoCKP within 5 s, corresponding to losses of 70, 50, 30, and 10 cents, respectively. The 'rest' option required no effort and resulted in a fixed loss of 90 cents (equivalent to earning 10 cents in experiment 1), applicable to either the participant or the receiver. Failure to achieve the desired outcome from the 'work' option resulted in a loss of 100 cents. Although the reward structure remained unchanged, the framing shifted to emphasize loss avoidance. Third, before starting the tasks, participants were given two sums of money (belonging respectively to oneself and the receiver), specified as being in addition to their existing participation fee. These amounts represented potential extra earnings by the end of the experiment. The actual additional amount earned depended on the

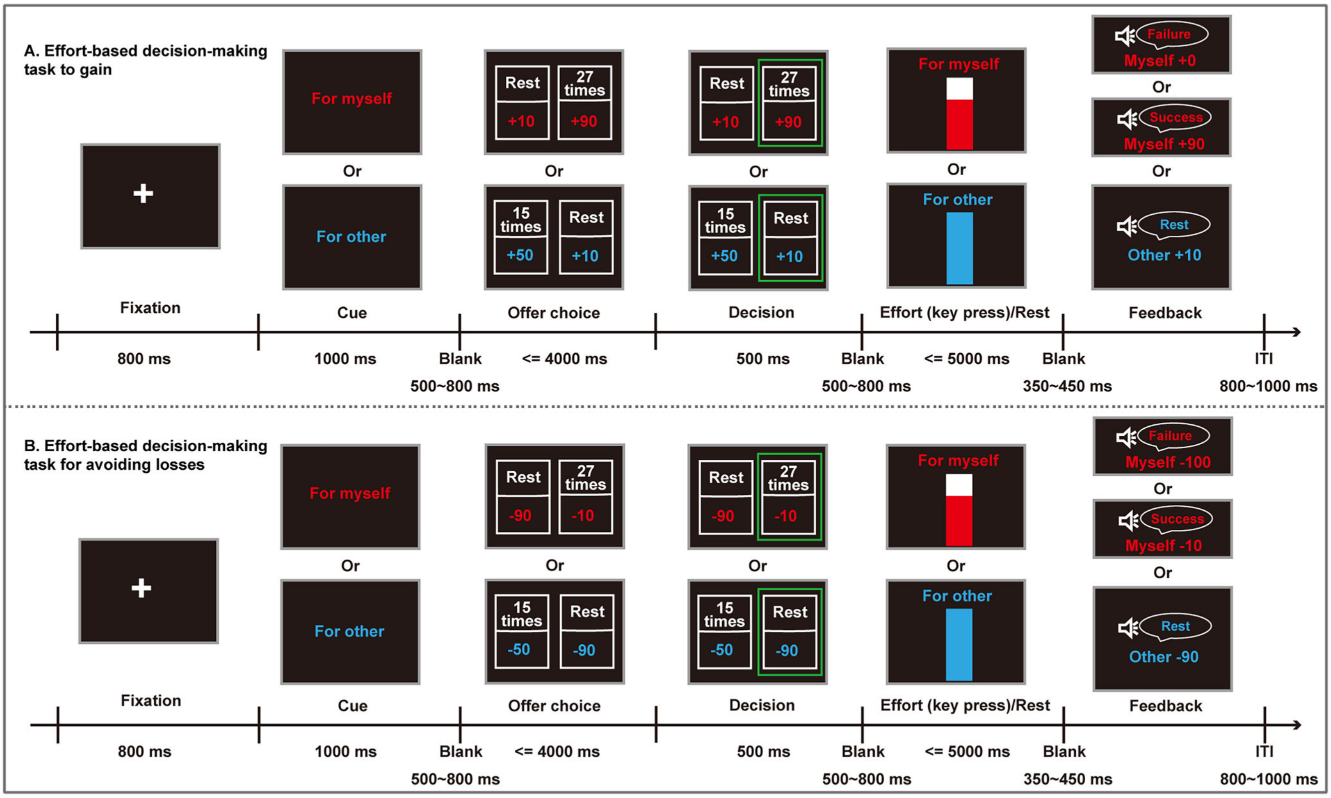

Fig. 1. The procedure of effort-based decision-making tasks. **Panel A:** Effort-based decision-making task of gain, each trial began with a white fixation cross for 800 ms, followed by a screen indicating the trial type (red for self, blue for receiver) for 1000 ms, then a blank screen for 500 to 800 ms. Participants then reached a decision screen where they made choices using the left or right arrow keys on a standard keyboard. The interface advanced automatically upon keypress. The chosen option was highlighted with a green box for 500 ms, followed by another blank screen for 500 to 800 ms. Selecting the work option displayed an empty bar on the screen. Participants had to press the 'Q' key a specified number of times within 5000 ms to earn the reward. As they pressed, the bar filled with color (red for self, blue for receiver). If completed within 5000 ms, the bar fully filled, and a blank screen followed for 500 to 800 ms. A screen then displayed the monetary reward earned for 1000 ms, accompanied by a 'success' sound. Failure to complete the presses within 5000 ms resulted in zero earnings display after a blank screen and a 'failure' sound. Choosing the rest option displayed a colored bar (red for self, blue for receiver) that remained onscreen for a random duration between 2000 and 5000 ms. This variability accommodated the immediate transition of the effort task interface upon completion of key presses. **Panel B:** Effort-based decision-making task for avoiding losses, the procedure closely followed those of panel A with two key modifications: (1) The new task focused on avoiding cents losses. (2) In the loss-avoidance task, each trial offered a choice between a 'work' option and a 'rest' option. The 'work' option required varying levels of effort—30 %, 50 %, 70 %, and 90 % of the participant's MNoCKP within 5 s—corresponding to losses of 70, 50, 30, and 10 cents, respectively. The 'rest' option required no effort and resulted in a fixed loss of 90 cents (equivalent to earning 10 cents in Experiment 1), applicable to either the participant or the receiver. Failure to meet the 'work' option's requirement resulted in a 100-cent loss. While the reward structure remained the same, the focus shifted to emphasize loss avoidance.

participant's performance in the loss-avoidance task. Any losses incurred by the participant, whether for themselves or the receiver, were deducted from these additional funds, with the remaining balance awarded to both the participant and the receiver.

Task-dependent measures

In alignment with the study's focus on participants' prosocial behaviors, the experimental task was structured into two distinct phases: the choice stimulus presentation and effort exertion. The choice stimulus presentation phase: In this phase, we measured two indicators of participants' willingness to engage in prosocial behaviors: **(1) Effort choice proportion:** Defined as the ratio of decisions to exert effort to the total decisions made in each condition following the presentation of the choice stimulus interface. This metric quantifies the extent to which participants are inclined to choose effortful responses; **(2) Effort choice reaction time (RT):** Captures the time elapsed in each condition from the presentation of the choice stimulus interface to the participant's decision to engage in an effortful choice. This measure reflects responsiveness to prosocial cues. Effort exertion phase: During this stage, two metrics were assessed to evaluate the intensity of the participants' efforts: **(1) Effort success rate:** The ratio of successful effortful key-press trials completed within the designated time frame to the total number of effortful decisions made in each condition. This metric gauges the effectiveness of the participants' efforts; **(2) Average RT per effortful key press:** This metric represents the average time taken for each key press executed during the effort phase. Calculated by dividing the total duration of key presses by the total number of key presses in each condition, it serves as an indicator of the temporal efficiency of the participants' responses during effortful tasks. These measures provide a comprehensive assessment of the participants' propensity and efficiency in engaging in prosocial behaviors, which is crucial for understanding the dynamics of social decision-making and effort exertion in human interactions.

Electroencephalographic recording and analysis

EEG data within the frequency range from DC to 100 Hz were continuously captured using the Brain Product System (Brain Products GmbH) at a sampling rate of 500 Hz. The 64 Ag-AgCl scalp electrodes were positioned according to the standard 10–20 system. The FCz electrode was utilized as the online reference, and impedances were maintained below 10 KΩ. To monitor eye movements and blinks, an electro-ocular signal was also recorded simultaneously using an IO electrode placed on the left lower eyelid.

We used MATLAB R2022b (MathWorks, USA) and the EEGLAB toolbox v2022.1 for preprocessing and analyzing EEG data (Delorme & Makeig, 2004). Our analysis focused on brain responses during two key phases: choice stimulus presentation and effortful key pressing. We therefore confined our examination to EEG signals from these phases. Continuous EEG signals were band-pass filtered between 1 and 40 Hz to isolate relevant frequencies (Chakladar et al., 2024; Deng et al., 2022; Hu et al., 2024; Yang et al., 2024). The segmentation parameters were precisely defined. During the choice stimulus presentation phase, data were segmented from 200 ms before to 1000 ms after stimulus onset, with baseline correction applied to the 200 ms preceding the stimulus. In the effortful key-pressing phase, data were segmented from 200 ms before to 1000 ms after effort initiation, using the 200 ms prior to the presentation of the effort interface for baseline correction. We visually inspected the data to remove trials with significant noise due to major movements, ensuring that this exclusion did not exceed 3 % of all trials. To address artifacts from eye movements and blinks, we applied the independent component analysis (ICA) algorithm.

Building on early effort-based decision-making research, we observed specific ERP responses across different task phases. In experiment 1 and 2, during the choice stimulus presentation phase, the P3 component was identified, showing mean amplitudes between 300 and 430 ms post-stimulus onset at central-parietal electrode sites C1, Cz, C2, and CPz (Cui et al., 2013; Sailer et al., 2010). These findings were based on grand average ERP scalp topographies and dominant ERP components.

During the effort phase of Experiments 1 and 2, the P1, P2, and P3 components were notably identified through the analysis of grand average ERP scalp topographies. In our study, the electrode locations and time windows selected for the same components in both experiments were consistent, as detailed below: The average peak amplitudes of P1 and the mean amplitudes of P3 were localized at electrodes PO7, PO3, POz, PO4, PO8, O1, Oz, and O2 (Gantiva et al., 2020; Sun et al., 2024; Wieser et al., 2012), occurring within time windows of 60–140 ms and 290–420 ms, respectively. The average peak amplitudes of P2 were localized at electrodes F3, Fz, F4, FC3, FCz, FC4, and Cz (Sun et al., 2024; Zhang et al., 2022; Zhou et al., 2022), with the selected time window of 140–280 ms. This structured approach enables us to precisely attribute changes in ERP components to specific task-related cognitive processes.

Statistical analysis

Experiments 1 and 2. For statistical analysis, SPSS version 26.0 (IBM Corp., New York, NY) was utilized. A three-way repeated measures ANOVA was conducted, which included one between-participant factor, Group (HSA vs. LSA), and two within-subject factors: Agent (Self vs. Other) and Context (Private vs. Public). This analytic approach was applied to both behavioral measures (such as effort choice proportion, effort choice RT, effort success proportion, and average RT per effortful keypress) and ERP responses (specifically, the peak amplitudes of the P1 and P2 components, and the mean amplitudes of the P3 component). A Bonferroni correction was employed for simple effect to control the type I error rate.

Results

Experiment 1

Behavioral results

Table S1 provides descriptive statistics ($M \pm SE$) of the effort choice proportion, effort choice RT, effort success rate and average RT per effortful key press in all situations of gain task. Table S2 contains a complete list of all statistical comparisons.

For effort choice proportion (Fig. 2**A**), the ANOVA revealed a significant main effect of the Agent ($F(1,70) = 7.14$, $p = 0.009$, $\eta_p^2 = 0.09$) and a significant three-way interaction of Group × Agent × Context ($F(1,70) = 4.94$, $p = 0.029$, $\eta_p^2 = 0.07$). In order to comprehend the three-way interaction's group effect, simple effects analyses showed that, in private context, the HSA group's effort choice proportion for other-gain was significantly lower than the LSA group's (LSA: 0.96 ± 0.02; HSA: 0.88 ± 0.02; $p = 0.015$); in public contexts, however, the difference between the HSA and LAS groups' effort choice proportion for other-gain was not significant (LSA: 0.94 ± 0.02; HSA: 0.90 ± 0.02; $p = 0.187$). Regarding the agent effect of three-way interaction, in both private (Self: 0.94 ± 0.01; Other: 0.88 ± 0.02; $p = 0.004$) and public (Self: 0.93 ± 0.02; Other: 0.90 ± 0.02; $p = 0.038$) contexts, the HSA group's chosen proportion of effort for self-gain was significantly higher than other-gain, but LSA group's effort choice proportion was no significant difference between different agent in the two contexts. However, when regarding the contexts effect of three-way interaction, no significant differences were observed between private and public contexts.

For effort choice RT, the ANOVA revealed a significant main effect of the Agent ($F(1,70) = 11.12$, $p = 0.001$, $\eta_p^2 = 0.14$), indicating that effort choice RT when making effortful decisions for self-gain was shorter than other-gain (Self: 659.04 ± 5.99; Other: 679.02 ± 5.99; $p = 0.001$).

For effort success rate, the ANOVA revealed a significant two-way interaction of Group × Agent ($F(1,70) = 7.66$, $p = 0.007$, $\eta_p^2 = 0.10$). Simple effects analyses showed that for the LSA group, the effort success rate when making efforts for self-gain was significantly higher than when making efforts to other-gain (Self: 95.9 % ± 0.9 %; Other: 94.5 % ± 0.9 %; $p = 0.004$). However, for the HSA group, there was no significant difference in effort success rate between different agents (Self: 94.3 % ± 0.9 %; Other: 94.7 % ± 0.9 %; $p = 0.375$). Moreover, when analyzing the group effect in the two-way interaction on effort success rate, no significant differences were observed between different groups.

For average RT per effortful key press (Fig. 2**B**), the ANOVA revealed a significant main effect of the Agent ($F(1,70) = 5.47$, $p = 0.022$, $\eta_p^2 = 0.07$). A significant two-way interaction of Agent × Context ($F(1,70) = 4.54$, $p = 0.037$, $\eta_p^2 = 0.06$), and a three-way interaction of Group × Agent × Context was also revealed ($F(1,70) = 4.47$, $p = 0.038$, $\eta_p^2 = 0.06$). In order to comprehend the three-way interaction's group effect, simple effects analyses showed that, in private context, the HSA group's average RT per effortful key press for other-gain was marginally longer than the LSA group's (HSA: 194.99 ± 6.60; LSA: 176.50 ± 6.60; $p = 0.051$); in public context, however, the difference between the HSA and LAS groups' average RT per effortful key press for other-gain was not significant (HSA: 190.15 ± 6.39; LSA: 175.44 ± 6.39; $p = 0.108$). Regarding the agent effect of three-way interaction, in private context, the HSA group's average RT per effortful key press for self-gain significantly faster compared to other-gain (Self: 188.66 ± 5.95; Other: 194.99 ± 6.60; $p = 0.004$). In contrast, in public context, HSA group was no significant difference between different agents in the average RT per effortful key press (Self: 189.37 ± 6.13; Other: 190.15 ± 6.39; $p = 0.545$). Furthermore, the LSA group did not exhibit any differences related to the agent factor under any contexts. However, when analyzing the effects of context of three-way interaction on the average RT per effortful key press, no significant differences were observed between different contexts.

ERP results

Table S1 presents descriptive statistics ($M \pm SE$) of electrophysiological components during the choice stimulus presentation and the effortful key pressing phase across all conditions of the gain task. The mean amplitudes of the P3 component during the choice stimulus presentation are shown. Additionally, the average peak amplitudes of the P1 and P2 components and the mean amplitudes of the P3 component during the effortful key pressing phase are provided. Table S2 offers a comprehensive list of all statistical comparisons. Fig. 2 displays the grand average ERP activity during the different conditions.

For the mean amplitudes of P3 during the presentation of the choice

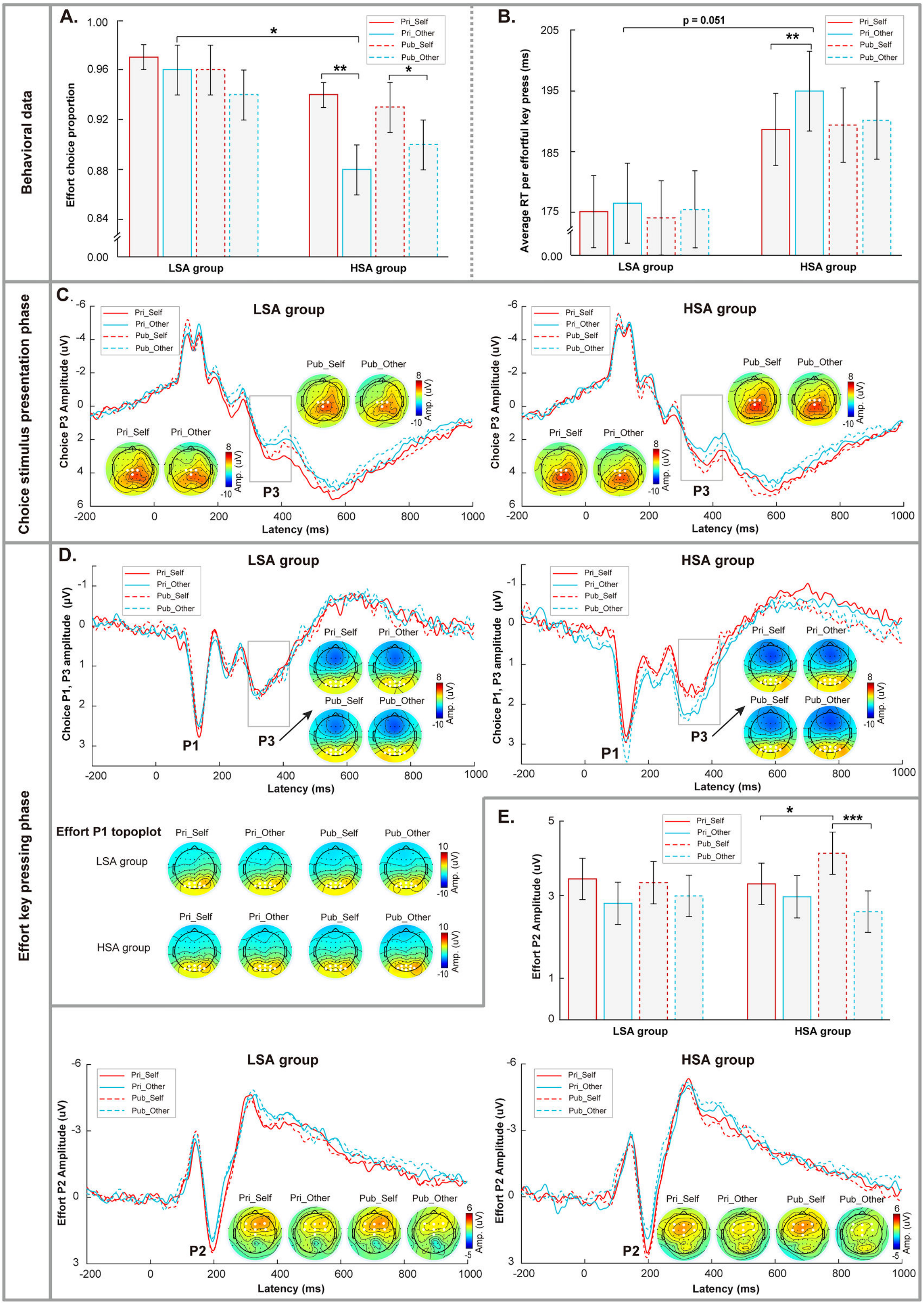

Fig. 2. Behavioral and ERP responses induced by effort-based decision-making task of gain. **Panel A:** Effort choice proportion is defined as the ratio of decisions to exert effort to the total decisions made in each condition after the choice stimulus interface is presented. **Panel B:** Average RT per effortful key press is calculated by dividing the total duration of key presses by the total number of key presses in each condition. **Panel C:** ERP waveforms and scalp topographies were recorded to investigate the participant's responses to different choice stimulus in choice stimulus presentation phase. The choice P3 mean amplitudes were measured at central-parietal electrode sites C1, Cz, C2, and CPz, and were compared across the different experimental conditions. In Panels D and E, ERP waveforms and scalp topographies were recorded to examine participants' responses to different effort conditions during the key-pressing phase. **Panel D** shows the P1 peak amplitudes and P3 mean amplitudes, measured at electrodes PO7, PO3, POz, PO4, PO8, O1, Oz, and O2, with comparisons made across experimental conditions. **Panel E** shows the P2 waveforms and topographies, recorded at electrodes F3, Fz, F4, FC3, FCz, FC4, and Cz, and compared across conditions. The electrodes used to evaluate the ERP amplitudes were marked with enlarged white dots on the corresponding scalp topographies. The data are presented as $M \pm SE$. Statistical significance was denoted as $^{*}p < 0.05$, $^{**}p < 0.01$ and $^{***}p < 0.001$.

stimulus (Fig. 2**C**), the ANOVA revealed a significant main effect of the Agent (F(1,70) = 14.39, $p < 0.001$, $\eta_p^2 = 0.17$), indicating that the mean amplitudes of P3 when viewing choice stimulus for self-gain was larger than for other-gain (Self: 2.71 ± 0.30; Other: 2.10 ± 0.31).

For P1 amplitudes during the effortful key-pressing phase (Fig. 2**D**), the ANOVA revealed a significant two-way interaction between Agent and Group (F(1,70) = 4.18, p = 0.045, $\eta_p^2 = 0.06$). Simple effects analyses to examine the agent effect within this interaction indicated that for the HSA group, the P1 amplitudes for self-gain were marginally smaller than those for other-gain (Self: 3.98 ± 0.39; Other: 4.29 ± 0.39; p = 0.060). Furthermore, when analyzing the group effect within the two-way interaction on P1 amplitudes, it was found that for the other-gain condition, the P1 amplitudes of the LSA group were marginally smaller than those of the HSA group (LSA: 3.20 ± 0.39; HSA: 4.29 ± 0.39; p = 0.050).

For P2 amplitudes during the effortful key-pressing phase (Fig. 2**E**), the ANOVA revealed a significant main effect of Agent (F(1,70) = 13.09, p = 0.001, $\eta_p^2 = 0.16$), indicating that peak P2 amplitudes for self-gain were larger than those for other-gain (Self: 3.50 ± 0.33; Other: 2.84 ± 0.34; p = 0.001). Additionally, a significant three-way interaction of Group × Agent × Context was observed (F(1,70) = 5.17, p = 0.026, η_p^2 = 0.07). To understand this interaction, simple effects analyses revealed that for the HSA group, in a public context, the P2 amplitude for self-gain was significantly larger than for other-gain (Self: 4.02 ± 0.51; Other: 2.61 ± 0.50; $p < 0.001$). In contrast, for the HSA group, no significant difference was found in the private context (Self: 3.28 ± 0.50; Other: 2.97 ± 0.51; p = 0.343). The LSA group did not show any significant agent effects in either context. Regarding the context effect within the three-way interaction, the HSA group's P2 amplitudes for self-gain were significantly larger in the public context compared to the private context (Private: 3.28 ± 0.50; Public: 4.02 ± 0.51; p = 0.035). However, for other-gain, there was no significant difference in P2 amplitudes between contexts (Private: 2.97 ± 0.51; Public: 2.61 ± 0.50; p = 0.283). Similarly, the LSA group did not exhibit any context-related differences for either agent. Finally, the analysis of the group effects within the framework of the three-way interaction on P2 amplitudes revealed no significant differences among the groups.

For mean amplitudes of P3 during the effortful key pressing phase (Fig. 2**D**), the ANOVA revealed a significant main effect of Agent (F (1,70) = 5.81, p = 0.019, $\eta_p^2 = 0.08$), indicating that the mean amplitudes of P3 during effortful key pressing for other-gain were larger than self-gain (Self: 1.42 ± 0.22; Other: 1.64 ± 0.22). Additionally, a significant two-way interaction between Group and Agent was found (F (1,70) = 5.03, p = 0.028, $\eta_p^2 = 0.07$). Simple effects analyses to understand the agent effect in the two-way interaction showed that in HSA group, the P3 mean amplitudes for other-gain was larger than self-gain (Self: 1.64 ± 0.31; Other: 2.06 ± 0.31; p = 0.002). Moreover, when analyzing the group effect in the two-way interaction on P3 amplitudes, no significant differences were observed between different groups.

Experiment 2

Behavioral results

Table S3 provides descriptive statistics ($M \pm SE$) of the effort choice proportion, effort choice RT, effort success rate and average RT per effortful key press in all situations of loss task. Table S4 contains a complete list of all statistical comparisons.

For effort choice proportion, the ANOVA revealed a significant main effect of the Agent (F(1,70) = 8.81, p = 0.004, $\eta_p^2 = 0.11$), indicating that the chosen proportion when viewing chosen stimulus for self-loss was higher than for other-loss (Self: 0.94 ± 0.01; Other: 0.93 ± 0.01).

For effort choice RT, the ANOVA revealed a significant main effect of the Agent (F(1,70) = 18.77, $p < 0.001$, $\eta_p^2 = 0.21$), indicating that the choice RT when making effortful decisions for self-loss was shorter than other-loss (Self: 759.54 ± 17.85; Other: 781.81 ± 19.21).

For effort success rate, the ANOVA revealed a significant main effect of the Agent (F(1,70) = 4.12, p = 0.046, $\eta_p^2 = 0.06$), indicating that effort success rate when making effortful decisions for self-loss was higher than other-loss (Self: 95.5 % ± 0.5 %; Other: 94.6 % ± 0.6 %).

For average RT per effortful key press (Fig. 3**A**), the ANOVA revealed a significant main effect of the Agent (F(1,70) = 21.02, $p < 0.001$, η_p^2 = 0.23). A marginally significant three-way interaction of Group × Agent × Context was also revealed (F(1,70) = 3.83, p = 0.054, $\eta_p^2 = 0.05$). In order to comprehend the three-way interaction's agent effect, simple effects analyses showed that: (1) in private context, the LSA group's average RT per effortful key press for self-loss significantly faster compared to other-loss (Self: 174.84 ± 6.04; Other: 178.36 ± 6.16; p = 0.002); (2) in public context, the LSA group's average RT per effortful key press for self-loss significantly faster compared to other-loss (Self: 176.28 ± 6.24; Other: 178.04 ± 6.3; p = 0.041); (3) in private context, the HSA group's average RT per effortful key press for self-loss significantly faster compared to other-loss (Self: 188.58 ± 6.04; Other: 191.20 ± 6.16; p = 0.021); (4) in public context, the HSA group's average RT per effortful key press for self-loss significantly faster compared to other-loss (Self: 184.82 ± 6.24; Other: 188.24 ± 6.3; $p < 0.001$). However, when analyzing the effects of group and context of three-way interaction on the average RT per effortful key press, no significant differences were observed between different groups and contexts.

ERP results

Table S3 presents descriptive statistics ($M \pm SE$) of electrophysiological components during the choice stimulus presentation and the effortful key pressing phase across all conditions of the avoiding loss task. The mean amplitudes of the P3 component during the choice stimulus presentation are shown. Additionally, the average peak amplitudes of the P1 and P2 components and the mean amplitudes of the P3 component during the effortful key pressing phase are provided. Table S4 offers a comprehensive list of all statistical comparisons. Fig. 3 displays the grand average ERP activity during the different conditions.

For the mean amplitudes of P3 during the presentation of choice stimulus (Fig. 3**B**), the ANOVA revealed a significant main effect of the Agent (F(1,70) = 9.89, p = 0.002, $\eta_p^2 = 0.12$) and a three-way interaction of Group × Agent × Context was also revealed (F(1,70) = 4.23, p = 0.043, $\eta_p^2 = 0.06$). In order to comprehend the three-way interaction's agent effect, simple effects analyses showed that, in private context, the mean P3 amplitudes of HSA group for self-loss significantly larger compared to other-loss (Self: 2.96 ± 0.53; Other: 2.06 ± 0.52; $p <$ 0.001). However, in the public context, there was no significant difference in mean P3 amplitudes between different agents (Self: 2.45 ± 0.55; Other: 2.57 ± 0.49; p = 0.642). In addition, the LSA group showed no significant differences in the mean amplitudes of P3 across different agents, both in private and public contexts. Moreover, when analyzing the effects of group and context of three-way interaction on the mean amplitudes of P3, no significant differences were observed between different groups and contexts.

For P1 amplitudes during the effortful key-pressing phase (Fig. 3**C**), the ANOVA revealed a significant main effect of Group (F(1,70) = 4.06, p = 0.048, $\eta_p^2 = 0.06$), indicating that, when faced with loss avoidance, peak P1 amplitudes in the HSA group were larger than those in the LSA group (LSA: 3.12 ± 0.36; HSA: 4.14 ± 0.36).

For P2 amplitudes during the effortful key-pressing phase (Fig. 3**D**), the ANOVA revealed a significant main effect of Agent (F(1,70) = 4.24, p = 0.043, $\eta_p^2 = 0.06$), showing that peak P2 amplitudes for self-loss were greater than those for other-loss (Self: 3.27 ± 0.31; Other: 2.91 ± 0.32). Additionally, a significant three-way interaction of Group × Agent × Context was found (F(1,70) = 4.38, p = 0.040, $\eta_p^2 = 0.06$). To further investigate this interaction of agent, simple effects analyses revealed that, for the HSA group in a public context, the P2 amplitude for self-loss was significantly larger than for other-loss (Self: 3.73 ± 0.49; Other: 3.09 ± 0.48; p = 0.036). In contrast, no significant difference was observed in the private context (Self: 2.96 ± 0.47; Other: 3.21 ± 0.48; p = 0.448). The LSA group did not demonstrate any significant agent

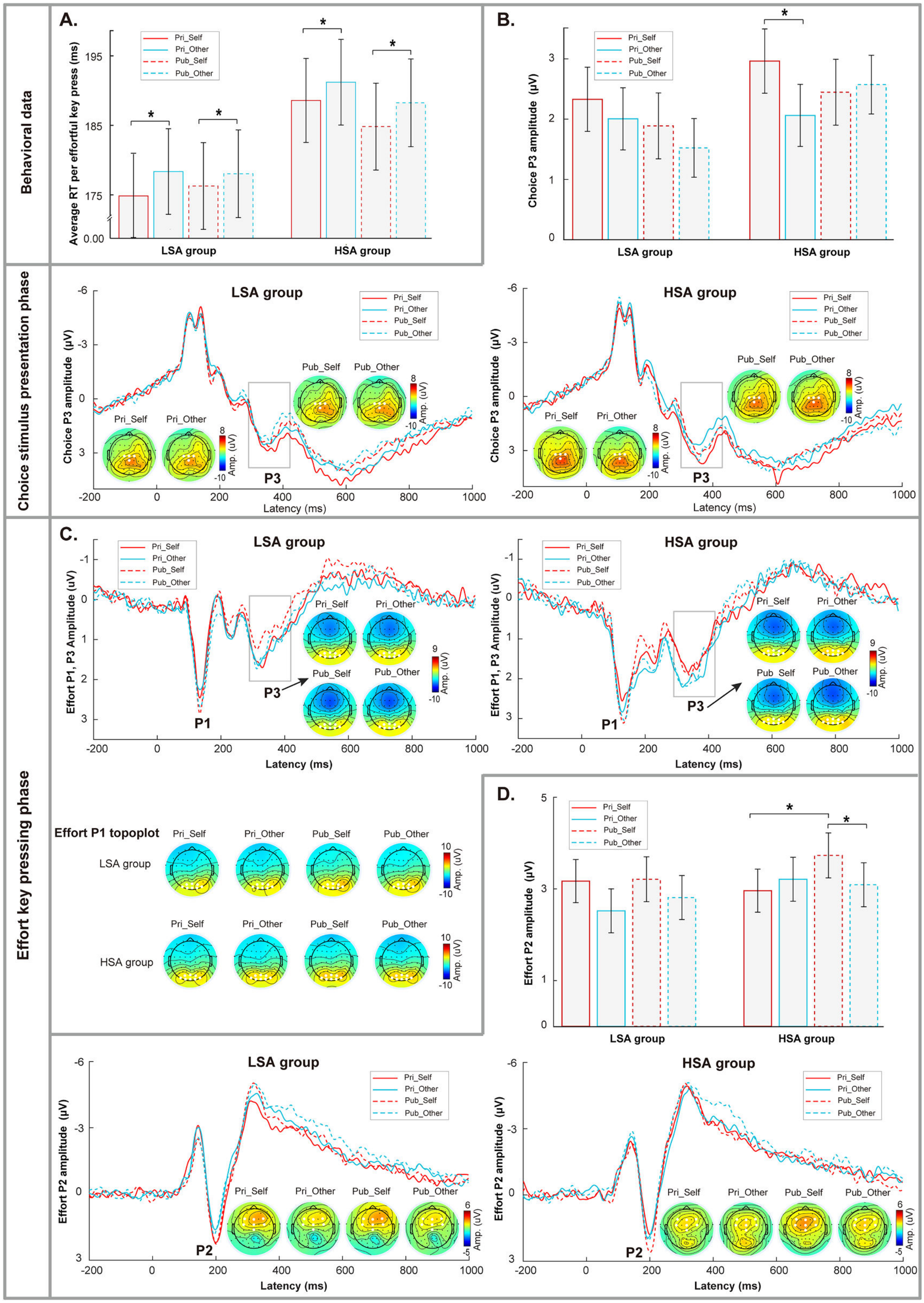

Fig. 3. Behavioral and ERP responses induced by effort-based decision-making task for avoiding losses. **Panel A:** Average RT per effortful key press represents the average time taken for each key press executed during the effort phase. Calculated by dividing the total duration of key presses by the total number of key presses. **Panel B:** ERP waveforms and scalp topographies were recorded to investigate the participant's responses to different choice stimulus in choice stimulus presentation phase. The choice P3 mean amplitudes were measured at central-parietal electrode sites C1, Cz, C2, and CPz, and were compared across the different experimental conditions. In Panels C and D, ERP waveforms and scalp topographies were recorded to examine participants' responses to different effort conditions during the key-pressing phase. **Panel C** shows the P1 peak amplitudes and P3 mean amplitudes, measured at electrodes PO7, PO3, POz, PO4, PO8, O1, Oz, and O2, with comparisons made across experimental conditions. **Panel D** shows the P2 waveforms and topographies, recorded at electrodes F3, Fz, F4, FC3, FCz, FC4, and Cz, and compared across conditions. The electrodes used to evaluate the ERP amplitudes were marked with enlarged white dots on the corresponding scalp topographies. The data are presented as $M \pm SE$. Statistical significance was denoted as $^*p < 0.05$.

effects in either context. Concerning the context effect within the three-way interaction, the HSA group's P2 amplitudes for self-loss were significantly higher in the public context than in the private context (Private: 2.96 ± 0.47; Public: 3.73 ± 0.49; $p = 0.035$). However, for other-loss, no significant differences in P2 amplitudes were found between contexts in the HSA group (Private: 3.21 ± 0.48; Public: 3.10 ± 0.48; $p = 0.735$). Similarly, neither agent showed any context-related differences in the LSA group. Finally, no significant variations between the groups were found when the group effects were analyzed within the three-way interaction framework on P2 amplitudes.

For mean amplitudes of P3 during the effortful key pressing phase (Fig. 3**C**), the ANOVA revealed a significant main effect of Agent (F (1,70) = 8.44, $p = 0.005$, $\eta_p^2 = 0.12$), indicating that the mean amplitudes of P3 during effortful key pressing for other-loss were larger than self-loss (Self: 1.21 ± 0.21; Other: 1.47 ± 0.21). Furthermore, no significant interactions were observed.

Discussion

Our study aimed to explore the impact of social anxiety on prosocial behavior, utilizing an effort-based decision task combined with ERP technology. We assessed the behavioral characteristics and neural responses of HSAs and LSAs during choice stimulus presentation and effort phases. Additionally, we examined how contexts and behavioral goals affect HSA individuals' prosocial behavior.

In experiment 1, we utilized an effort-based decision task to study how individuals strive for gains. We found that HSAs predominantly made decisions favoring self-gain over other-gain, showing a stronger preference for self-gain in both private and public contexts. However, LSAs did not exhibit such agent-based differences in either context. This may indicate that HSAs are willing to exert effort and take risks for self-gain but are less inclined to do so for other-gain because they do not receive actual monetary rewards for other-gain. Moreover, whether in private or public contexts, making an effort for other-gain might involve the risk of failure. Previous research has shown that HSAs tend to fear potential risks and, therefore, avoid them (Lorian & Grisham, 2010; Rapee & Heimberg, 1997), which might explain their reluctance to make effortful decisions for the benefit of others. Additionally, electrophysiological data from the choice stimulus presentation phase revealed that P3 amplitudes for self-gain decisions significantly exceeded those for other-gain decisions. This suggests that during the choice stimulus presentation process, individuals carefully evaluated the value of options, with self-gain decisions evidently holding greater value than those benefiting others. This finding aligns with prior studies (Guo et al., 2016; Lin et al., 2018; Parvaz et al., 2007; San Martín, 2012). Therefore, when faced with the decision to exert effort for other-gain, the aversion to risk and the lower subjective value of these decisions led HSAs to make fewer effortful decisions. These results partially support our **hypothesis 1**, which proposes that HSAs exhibit prosocial apathy at the decision-making level. However, these findings suggest that differences in P3 amplitude are solely related to prosocial apathy during choice stimulus presentation, independent of context and social anxiety, which contradicts **hypothesis 3**.

Although the HSA group made a higher proportion of effort decisions for self-gain than for other-gain in both private and public contexts, once they decided to exert effort, their efficiency in making efforts for self-gain and other-gain was similar in public contexts. However, in private contexts, HSAs were significantly more efficient in making efforts for self-gain than for other-gain. In the effort phase of experiment 1, a dynamic progress bar indicating the participants' keystroke progress was displayed in real-time at the center of the computer screen, serving merely as a visual cue. The primary objective for the participants was to concentrate on the keystroke task and complete the required number of presses within the designated time. It is possible that, compared to efforts for self-gain, the perceived subjective value of efforts for other-gain was lower, and HSAs were more easily attracted to salient and potentially threatening visual information (Moriya & Tanno, 2009), such as the dynamic bar reflecting their real-time performance. Consequently, their attention was more focused on visual stimuli rather than on completing the effort task. In private contexts, there was no pressure from fear of evaluation by others to drive them to perform better. In public contexts, however, we propose that, regardless of whether the task involves self-gain or other-gain, participants are confronted with the potential risk that their performance may be observed and evaluated by others. This increased possibility of social evaluation likely leads HSAs to experience heightened anxiety and vigilance during the effort phase in public contexts, compared to private contexts. The P2 amplitude during this phase revealed that, for HSAs, P2 amplitudes were significantly larger for self-gain in public contexts compared to private contexts. Moreover, in public contexts, self-gain induced larger P2 amplitudes than other-gain. In contrast, LSAs did not show any significant differences in P2 amplitudes across conditions. These results suggest that in public contexts, where the risk of being observed and evaluated is heightened, HSAs exhibit greater attentional vigilance and engage in more complex motivational processes compared to private contexts. These findings contradict Hypotheses 4. We speculate that, despite the higher subjective value of self-gain potentially driving self-serving decisions, the fear of negative evaluation when helping others may lead HSAs to focus more on the outcome of their performance. Consequently, HSAs may adopt a compensatory strategy to ensure successful performance, when exerting effort in public contexts (Arkin et al., 1986). This strategy involves allocating more attention to the task to ensure sufficient effort and avoid negative outcomes (Eysenck et al., 2007). This finding is consistent with the motivational concerns theory of social anxiety (Arkin et al., 1986; Meleshko & Alden, 1993), which suggests that in public contexts where individuals are likely to be evaluated, those with HSA are particularly motivated to avoid negative evaluations from others. This avoidance motivation leads them to employ compensatory strategies during effort-based tasks to ensure they perform adequately (Eysenck et al., 2007). As a result, while there were distinct behavioral differences in private contexts, these differences did not appear in public contexts. These findings suggest that in public contexts, HSAs may make fewer prosocial decisions due to aversion to risk and lower subjective value assessments. However, when they engage in prosocial actions in public, driven by evaluation anxiety, they use compensatory strategies to ensure successful outcomes for other-gain.

Furthermore, the behavioral data showed that in private contexts, HSAs made fewer prosocial effort decisions and exhibited longer average RT per effortful key press (approaching significance, $p = 0.051$) compared to LSAs, indicating lower prosocial intentions and effort levels. However, no significant differences in prosocial decision-making or effort levels were found between HSA and LSA groups in public contexts. These findings are inconsistent with **hypothesis 2**. Previous research indicated that HSAs, even when alone, are more easily attracted to salient and potentially threatening visual information, showing an attentional bias towards these types of stimuli, which leads to difficulty disengaging attention (Moriya & Tanno, 2009; Rossignol et al., 2012). Therefore, compared to LSAs, the attentional bias may affect the task performance of HSAs. Additionally, their aversion to risk leads HSAs to make fewer prosocial decisions when considering others-gain. Moreover, electrophysiological data from the effort phase revealed that the HSA group exhibited significantly higher P1 and P3 amplitudes for other-gain stimuli compared to self-gain stimuli. In contrast, the LSA group showed no significant differences in P1 and P3 amplitudes in response to the agent. These findings contradict Hypothesis 4 and 5. Previous research has demonstrated that P1 and P3 amplitudes are respectively associated with the early and late allocation of attention to visual stimuli during task completion (Liu et al., 2024; MacNamara et al., 2009). Specifically, greater attentional allocation to stimuli corresponds to larger P1 and P3 amplitudes. Consistent with these findings, our results suggest that HSAs, who were focused on real-time self--performance, had trouble shifting their attention from performance-related visual stimuli to the keystroke task when exerting effort on behalf of others. This difficulty in reallocating attention likely contributed to their longer RT when exerting effort on behalf of others. In contrast, in public contexts, intense evaluative anxiety prompted HSAs to adopt compensatory strategies such as heightened attention to the task rather than visual stimuli, thus reducing performance disparities and aligning their behavioral and neural responses with those of LSAs. These findings consistently show that while social anxiety can impair prosocial intentions and effortful efficiency due to aversion to risk and difficulty disengaging from self-performance-related visual stimuli, evaluative anxiety causes HSAs to concentrate more intensively at the start of tasks. This enhanced focus improves their performance and aligns their prosocial behaviors with those of LSAs.

Experiment 1, based on an effort-based decision-making task to gain, demonstrates the following: (1) HSAs exhibit prosocial apathy both during prosocial decision-making and in the effort phase; (2) HSAs tend to make fewer prosocial decisions due to aversion to risk and lower subjective value. However, once they do make prosocial decisions in public (evaluative) context, the anxiety associated with being evaluated mitigates their prosocial apathy during the effort phase. (3) Social anxiety impairs prosocial behaviors in individuals. Nevertheless, evaluative anxiety prompts HSAs to employ compensatory strategies early in the effort process, enhancing their level of effort and ultimately aligning their prosocial performance with that of LSAs.

In experiment 2, we investigated an effort-based decision-making task focused on avoiding losses. Participants were more willing to exert effort and made decisions more quickly when the effort was directed at avoiding self-loss rather than avoiding other-loss. Additionally, success rates significantly increased when efforts were self-loss rather than other-loss, suggesting the presence of prosocial apathy in tasks designed to avoid losses. During the choice stimulus presentation phase, HSAs in private context exhibited significantly higher P3 amplitudes when facing choices to avoid self-loss compared to other-loss. However, this difference in P3 amplitudes was not evident in public contexts for HSAs, nor was it observed for LSAs in either context. Given that larger P3 amplitudes indicate more substantial subjective valuation and preference in decision-making (San Martín, 2012), suggesting that in private contexts—where there is no risk of being judged—HSAs place a higher subjective value on minimizing personal losses. In contrast, exerting effort for others, which does not directly benefit oneself, leads to a significantly lower subjective value being assigned to such decisions. Consequently, the P3 amplitude for self-loss in private contexts is significantly higher than for other-loss. Moreover, HSAs, particularly those who fear judgment, tend to evaluate the consequences of their decisions more carefully in public contexts. Therefore, opting to minimize personal losses is considered valuable, but the anxiety associated with being evaluated in public contexts significantly diminishes this value, resulting in no significant difference in the subjective value between decisions to avoid self-loss versus those to avoid other-loss. Conversely, LSAs, who do not fear severe evaluative anxiety and do not have an aversion to risk, show sensitivity to losses affecting both themselves and others. They show no difference in P3 amplitudes in either context during the later phases of choice stimulus presentation. This indicates that the context of being evaluated induces anxiety in HSAs, significantly reducing their subjective valuation of self-loss decisions, which reflects a more refined, top-down process occurring later in the choice stimulus presentation.

Additionally, in the effort phase of Experiment 2, regardless of whether the context was public or private, both HSAs and LSAs exhibited faster average RT per effortful key press for self-loss than for other-loss, indicating a higher level of effort. This finding supports the concept of loss aversion, which suggests that individuals are more sensitive to avoiding losses than to achieving gains, potentially fostering prosocial apathy across different contexts. Moreover, electrophysiological data revealed no significant differences in P1 and P3 amplitudes in any context. However, in private contexts, HSAs exhibited significantly lower P2 amplitudes when exerting effort to avoid self-loss compared to public contexts. Additionally, in public contexts, HSAs showed significantly higher P2 amplitudes when avoiding self-loss than when avoiding other-loss. No such differences in P2 amplitudes were observed among LSAs, regardless of the context. These P2 amplitude results are consistent with those from Experiment 1. The findings suggest that in public contexts, where the risk of being observed and evaluated is heightened, HSAs exhibit greater attentional vigilance and engage in more complex motivational processes compared to private contexts. However, the behavioral data from Experiment 2 indicate that HSAs exerted less effort to avoid other-loss in public contexts compared to self-loss. Based on the electrophysiological data, it can be inferred that in public contexts, HSAs are indeed more vigilant and motivated, which leads them to employ compensatory strategies to augment their attentional resources and exert greater effort to avoid losses for both them and others during the effort phase. Despite the heightened vigilance and stronger motivation to avoid self-loss in public contexts, loss aversion (Tversky & Kahneman, 1991, 1992)—especially with respect to self-loss—appears to drive HSAs' greater effort when avoiding self-loss compared to other-loss. In contrast, in private contexts, although no significant differences in P2 amplitudes were observed between self-loss and other-loss conditions, their aversion to loss still led to greater effort when avoiding self-loss. These findings confirm that both HSAs and LSAs exhibit a robust aversion to losses, which can lead to prosocial apathy. However, the threat of social evaluation may enhance HSAs' vigilance but does not significantly alter their level of prosocial effort. Despite this, the sensitivity to losses does not appear to significantly affect prosocial performance between HSAs and LSAs across different contexts, nor does it impact prosocial decisions or efforts. To some extent, this sensitivity may mitigate the negative impact of social anxiety on prosocial behavior.

In experiment 2, which focused on effort-based decision-making tasks for avoiding losses, we observed results consistent with those of experiment 1. Specifically, in private context, regardless of whether the task involved avoiding losses or gaining rewards, HSAs demonstrated greater concern for their own interests and exhibited prosocial apathy. However, unlike in experiment 1 where the anxiety of being evaluated reduced prosocial apathy about effort level among HSAs during gain tasks in public context, in experiment 2, similar public contexts involving the more sensitive issue of losses did not affect the HSAs' prosocial apathy about effort level. Additionally, in the private contexts of experiment 2, we did not find the same differences in prosocial decisions and efforts between HSAs and LSAs as observed in experiment 1. We propose that both groups may be similarly sensitive to others' losses, such that even HSAs, who typically show less prosocial inclination and effort in gain tasks, aligned with LSAs in their behavioral responses. This could be due to a loss aversion effect prompting HSAs to engage more in prosocial decisions and efforts. It is important to note that the conclusions drawn about prosocial behavior in effort-based loss avoidance tasks require further validation through additional research. This is particularly because these findings were obtained from simple effects comparisons under conditions where the three-way interaction (average RT per effortful key press) was marginally significant ($p = 0.054$).

This study is the first to employ a combination of effort-based decision-making tasks and electrophysiological techniques to explore the impact of social anxiety on different phases of prosocial behavior, incorporating factors such as context and behavioral goals to more comprehensively understand the mechanisms of prosocial behavior in HSAs. Our research provides compelling evidence that social anxiety indeed impairs individuals' prosocial intentions and motivational efforts. However, once HSAs make prosocial effort decisions, evaluative anxiety enhances their vigilance and prompts them to adopt compensatory strategies, thereby bringing their level of prosocial effort closer to that of LSAs. Furthermore, HSAs exhibit prosocial apathy whether facing gains or losses, but this apathy is more pronounced when dealing with losses as compared to gains. Additionally, when making efforts to avoid losses for others, even in private context, HSAs demonstrate prosocial behaviors indistinguishable from those of LSAs, suggesting that sensitivity to losses might reduce the negative impact of social anxiety on prosocial behavior. Overall, while social anxiety diminishes individual prosocial behavior, evaluative anxiety and sensitive action goals can mitigate its impact to some extent. These findings hold significant implications for advancing human psychological health and building healthy social relationships.

Although the findings of this study favorably demonstrate the characteristics and influencing factors of prosocial behavior in individuals with social anxiety, thereby aiding future research and interventions in this field, the study is not without limitations. First, while we distinguished participants based on the presence of severe depression, we did not categorize the HSAs based on whether their condition of social anxiety had reached a clinical disorder level. Future research might consider dividing participants into three groups: LSA, HSA, and social anxiety disorder (SAD), to address this aspect. Secondly, the effort-based decision tasks used in our study primarily involved physical effort and did not engage cognitive aspects, which made the tasks relatively simple. This simplicity might limit the applicability of our findings to more complex cognitive tasks; whether the results would be replicable in such settings remains to be seen. Thirdly, while behavioral and electrophysiological studies have enabled us to understand the characteristics and influencing factors of prosocial behavior in HSAs from psychological and immediate cognitive perspectives, the low spatial resolution of ERP methods precludes in-depth exploration of the neural mechanisms and circuits driving these behaviors. Future studies could integrate EEG with fMRI techniques to explore the prosocial mechanisms of HSAs from psychological, cognitive, temporal, and spatial perspectives more effectively.

CRediT authorship contribution statement

Ye Yang: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Visualization, Writing – original draft, Writing – review & editing. **Yan Zhou:** Conceptualization, Methodology, Visualization, Writing – review & editing. **Huijuan Zhang:** Methodology, Visualization, Writing – review & editing. **Hui Kou:** Methodology, Writing – review & editing. **Jia Zhao:** Methodology, Writing – review & editing. **Jiangli Tian:** Data curation. **Cheng Guo:** Conceptualization, Methodology, Formal analysis, Data curation, Visualization, Writing – review & editing, Supervision, Funding acquisition.

Declaration of competing interest

The authors declare that they have no conflicts of interest.

Data and code availability statements

The data in the present study are available upon reasonable request to the corresponding author. No customized codes were used in this study.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.ijchp.2024.100533.

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