Socially informed control inferences inform generalisation of control beliefs

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Abstract

Perceived control in one context can affect behaviour in novel contexts. One potentially important variable determining generalisation is how perceived control in one context shapes beliefs about the self. Typically, learned helplessness studies do not control or manipulate this factor. Here, we test whether observing others' ability to exert control helps to inform inferences about whether the controllability is primarily due to one's own ability or a feature of the current environment, and thereby determines the degree of generalisation. In an initial study (N=200) and pre-registered replication study (N=436) we used comparative social feedback about performance in a novel task (the Wheel Stopping task) to assess how self- or environment-specific inferences shape control beliefs. Linear mixed effects models revealed that both task controllability and social feedback uniquely predicted participants' local control beliefs (trial-by-trial), after accounting for perceived task difficulty in both studies. Additionally, in Study 2, there was a significant decrease of internal locus of control in the group with self-specific feedback in the low control condition, suggesting that in low-control scenarios, self-specific inferences of control impact global control beliefs. Study 2 further revealed that task controllability and feedback were not related to changes in reported self- versus task-specific attribution of control, nor was there evidence of generalisation to impact performance in a second stressor controllability task. These results suggest that comparative social feedback shape local and global control beliefs but do not change reported self- or task-attribution of control, or predict behaviour during a second task.

Keywords: control beliefs, agency, attribution, social feedback.

Public Significance Statement: This study highlights that social information (being informed of task performance relative to others) shapes the amount of control individuals believe they have in that moment in time on a specific task, serving as a mechanism that supports generalisation to novel scenarios. Such generalisation was limited to control beliefs following experiences of low control.

Introduction

Decades of research has shown that the controllability of a stressor has profound effects on subsequent behaviour. Repeated episodes of uncontrollable stress can lead to "learned helplessness" while controllable stress can confer resilience and inoculate against later stress (Maier & Seligman, 2016). Both the subjective experience of control and the causal attributions about *why* one is in/out of control are important aspects to these phenomena (Abramson et al., 1978; Hartley et al., 2014). A pervasive feature of learned helplessness is that experiences of lack of control generalise to new contexts (Huys & Dayan, 2009; Lieder et al., 2013). Such generalisation may be underpinned by contextual similarities in the environment, or by beliefs we hold about ourselves that transcend contexts and guide behaviour in novel contexts (Moscarello & Hartley, 2017). While controllability can be inferred from direct experience of action-outcome contingencies (Haggard, 2017), these are often noisy and ambiguous, and thus other sources of information are important in shaping controllability inferences (Blackburne et al., 2025). Observing whether others are (un)able to exert control in the same environment allows one to efficiently draw inferences about whether controllability is primarily due to one's own ability or a feature of the current environment, which makes social information potentially a key contributor to controllability inferences. Here, we investigate how social information informs control beliefs and how these beliefs generalise to a new context.

Over the last 50 years a large body of research has demonstrated that the controllability of a stressful scenario has profound effects not just on current but also on subsequent behaviour (Maier & Seligman, 2016). Typically, studies employ a triadic design, whereby rodents are exposed to a stressor (e.g. electric shocks) that is either escapable (controllable), inescapable (uncontrollable, but yoked to the controllable group), or do not receive any shocks. Those exposed to uncontrollable shocks are less likely to learn to escape a subsequent different (controllable) stressful task (Amat et al., 2006; Hiroto, 1974; Hiroto & Seligman, 1975;

Seligman & Maier, 1967). This behaviour was coined "learned helplessness". In contrast, the group exposed to controllable stress is more likely to learn to escape subsequent stressors than the group who was not exposed to *any* stress, demonstrating a "stress-inoculation" effect (Amat et al., 2006; Hartley et al., 2014; Maier & Watkins, 2010). Exposure to uncontrollable stress has been found to reduce social interaction and potentiate fear conditioning in animals as well as humans (Amat et al., 2010; Hartley et al., 2014), mirroring symptoms of depression and anxiety. Thus, while uncontrollable stress has been proposed to play a role in the aetiology of depression and anxiety, exposure to controllable stress has been found to facilitate fear extinction and is a marker of behavioural resilience (Feder et al., 2009; Hartley et al., 2014; Maier & Watkins, 2010; Southwick & Charney, 2012). The controllability of a stressor therefore has knock-on-effects after experiencing the stressor itself, and this generalisation is a pervasive feature of stressor controllability (Lieder et al., 2013).

Research with humans has adapted the original triadic design (e.g., Hiroto & Seligman, 1975) replicating the learned helplessness phenomena and spawned interest in the cognitive factors underpinning the observed generalisation (Mineka & Hendersen, 1985). The so-called attributional reformulation hypothesis proposes that the *explanations* for people's helplessness (the causal attributions made) may be more important for subsequent behaviour than the *inescapability* itself (Abramson et al., 1978), for example being told whether a loud, stressful noise stopped due to participants' actions, or because it was scheduled to do so (Miller & Seligman, 1975, for similar work also see Glass et al., 1973). The attribution reformulation of learned helplessness argues that the generalisation of helplessness depends on the causal attribution that the person makes about the uncontrollable events in the original situation (Abramson et al., 1978). An attributed cause can be either internal or external (from one's own efforts or external factors such as luck or chance), specific or global (specific to the situation or more general), and stable or unstable (permanent or temporary). The theory predicts that internal, stable, and global attributions for lack of control are more likely to lead to longer-lasting generalised helplessness effects, whereas individuals who make external, unstable, specific attributions for lack of control will show less generalisation and less persistent helplessness effects. By assessing individual differences in attributional styles to negative events (e.g. using the Attributional Styles Questionnaire by Peterson et al., 1982), research has provided correlational evidence to support these predictions (Alloy et al., 1984; Metalsky et al., 1982; Mineka & Hendersen, 1985). Thus, specific beliefs about one's ability to exert control appears to be a crucial factor driving observed generalisation of experiences of control.

Beliefs are a crucial dimension to the experience of control. This is because environments are often uncertain, controllability is rarely directly observable and must therefore be inferred. This can be achieved by evaluating action-outcome contingencies. If an action reliably and uniquely predicts a desired outcome, the scenario is controllable (Huys & Dayan, 2009; Moscarello & Hartley, 2017; Penton et al., 2022). Prior work suggests that a mismatch between a prospective signal that represents the intended outcome and a retrospective signal that represents the actual outcome of an action (prediction error signal) leads to an updated sense of agency (Haggard, 2017; Haggard & Chambon, 2012). Despite the importance of direct experience, action-outcome contingencies can be ambiguous, and other information is likely used to help shape our inference of control (Blackburne et al., 2025). One crucial source of information about whether environments are controllable is afforded by observing and comparing ourselves to others (Festinger, 1954). Prior research related to agency, found that self-efficacy, an individual's belief in their capacity to execute behaviours necessary to produce specific goals (Bandura, 1977, 1997), increased after giving participants rigged high comparative performance feedback during a task (e.g. scoring in the top 20%) as well as information that task improvement was possible. Furthermore, this led to subsequent improvement in a visual discrimination task, compared to when participants were given low feedback and told that improvement in the task is not possible (Zacharopoulos et al., 2014). Akin to other self-beliefs such as self-esteem (Will et al., 2017), control beliefs may be influenced by comparative social information. Importantly, social observation provides detailed information about whether controllability is a generic feature of a given environment (i.e. where everyone has / does not have control), or in fact specific to oneself (i.e. only I do / do not have control). In this study we refer to these as task-specific and self-specific inferences, respectively. These inferences ought to be pivotal in driving generalisation to novel environments, whereby self-specific inferences are arguably more internal and global than environment-specific ones given such an inference transcends contexts. Here we directly test whether socially informed inferences about oneself or the environment represent a potential mechanism of generalisation.

Cumulative prior experiences of control are proposed to aggregate to form a more global estimate of agency. If environments are consistently controllable then a higher-order estimate would be of high agency (Moscarello & Hartley, 2017; Rotter, 1966). In novel situations where the action-outcome contingencies are not known, a global agency estimate provides a best guess of the probability that the new environment will be controllable, which can be used to guide behaviour (Moscarello & Hartley, 2017). Control can therefore be experienced at multiple levels: at a local level (i.e. "does my *action* result in the desired *outcome*?"), at a situational level ("do my actions tend to result in the desired outcomes *in this context?*") and at a global level ("do I *generally* have control over my environment?"). This hierarchical formulation of control has been tested computationally using a Hierarchical Bayesian model which can accurately simulate learned helplessness behaviour (Lieder et al., 2013). The local-global hierarchical framework is also well documented and has been experimentally tested in a similar domain, metacognition (Rouault et al., 2019; Rouault &

Fleming, 2020; Seow et al., 2021), which links trial-by-trial estimates of task performance confidence to more general self-beliefs like self-esteem.

There are multiple theories concerning global estimates of perceived control, such as locus of control (Rotter, 1966), self-efficacy (Bandura, 1977), and self-determination (Deci & Ryan, 1985). The commonality of these theories of perceived control is the belief in one's ability to exert control over situations or events in order to gain rewards and avoid punishments (Ly et al., 2019). Locus of control is the belief that situations are within (internal) or outside (external) one's control (Rotter, 1966). Here, we focus on locus of control as our measure of global control beliefs given the distinction of the self and the environment (internal and external, respectively) which aligns well with the task-specific and self-specific inferences in this study.

As evidence of the pervasive impact of such global beliefs, meta-analyses have found that a more external locus of control is related to depression (Benassi et al., 1988; Presson & Benassi, 1996), and locus of control is found to mediate the relationship between early life socioeconomic adversity and depression at 18-years-old (Culpin et al., 2015) and between children's insecure attachment and internalising problems (Di Pentima et al., 2019). Furthermore, people's general sense of control has been found to predict psychological well-being (de Quadros-Wander et al., 2014) and resilience in times of crisis (Krampe et al., 2021; Yang & Ma, 2020). There is evidence that locus of control (a global estimate of control) influences more local experiences of control, as people with a more internal locus of control confront adverse situations in a more determined and calmer way (Leontopoulou, 2006). Like learned helplessness and stressor controllability, therefore, more global beliefs about one's control are linked to mental health in terms of both depression and anxiety and external locus of control, and resilience and internal locus of control.

In the present study, we measure control beliefs at local (trials), situational (tasks), and global (locus of control) levels. We sought to test whether providing social information via comparative performance feedback, designed to experimentally manipulate participants' attribution of control, would impact 1) local control beliefs, 2) situational perceived attribution of control and 3) performance on a second, different task, indicating generalisation. We first present findings from an initial exploratory study (Study 1, N=200) that manipulated feedback during a previously established Wheel Stopping task in high and low control versions (Fielder et al., 2025) where we find high or low feedback significantly shifts local control beliefs. We then present a pre-registered replication study (Study 2, N=436), which also tests for the effects of feedback on explicit attribution and generalisation to a second stressor controllability task where participants must learn to shuttle a counter across a grid to terminate an audible scream. Finally, we present exploratory analyses, suggesting that feedback may shift global control beliefs, specifically internal locus of control.

Methods

Ethics

The studies were approved by UCL research ethics committee (Study 1: 12271/003; Study 2: 12271/008). Electronic informed consent was obtained from all participants. All participants were debriefed after the study that the relative performance feedback was fabricated. Study 1 took approximately 25 minutes and participants were reimbursed £2.95 (£7.08/hr) with the opportunity to win bonus money depending on their performance in the Wheel Stopping task (1p per correct trial; mean bonus = 56p, range 23-85p). Study 2 took approximately 30 minutes are participants were reimbursed £5 (£10.00/hr, in line with increased reimbursement rates between Study 1 and Study 2) with the opportunity to keep a £3 bonus allocated to them at the start of the experiment if a randomly selected trial during the Wheel Stopping Task was correct (61.5% of participants kept the bonus).

Pre-registration

Study 1 was not pre-registered. The experiment, recruitment plan, hypotheses, and analyses for Study 2 were pre-registered on the Open Science Framework prior to data collection (https://osf.io/964cj).

Participants

Participants were recruited online via Prolific (www.prolific.com) in April 2022 (Study 1) and February 2025 (Study 2). Study 1 recruited 200 participants (50.5% female) aged 19-35 years old (*M*=28.1, *SD*=4.7) and Study 2 recruited 436 participants (47.2% female) aged 18-35 years old (*M*=27.8, *SD*=4.5). All participants resided in the UK. The majority had UK Nationality (Study 1: 87.5%; Study 2: 76.8%) and English as their first language (Study 1: 90.0%; Study 2: 88.1%). Ethnicity was assessed using five categories: Asian, Black, Mixed, Other, White and collected from Prolific for Study 2 only. The Study 2 sample were predominantly White (68.3%), with a mean education rating of 3.83 (SD=0.89) ranging from 1 (no formal qualifications) and 5 (postgraduate qualifications), and a mean subjective socioeconomic status (SES) level of 5.39 (SD=1.59) on the MacArthur 10-rung ladder (range 1-9 of a possible 1-10), though we were missing subjective SES data for n=52 (11.9%) due to a technical error. See Supplementary Information for full details of the socioeconomic and education measures.

We recruited only participants with Prolific approval rates of 90-100% (Studies 1 and 2) and those without hearing difficulties or hearing loss (Study 2) given the use of audio. Participants in Study 2 had to pass an initial headphone check and pitch discrimination task to continue to the experiment.

Study 1 recruited participants sequentially for each experimental condition, while Study 2 randomly allocated participants into the experimental conditions at the start of each experimental run. For Study 2 we pre-registered an intended sample size of n=368 (n=92 per group) based on a power calculation of obtaining 0.8 power to detect a small-medium effect size (f=0.175) at an alpha error probability of 0.0125 (0.05/4, given 4 main primary analyses) based on an ANOVA with 4 groups and a numerator df of 1 (using G*Power version 3.1.9.6, Faul et al., 2007). As pre-registered for Study 2, we checked the assignment of experimental conditions at 75% of the pre-registered sample size to check one group was neither over nor under sampled (one group 1.5 times larger than another). At this point, no conditions were under/over sampled, although one was close to the cut-off (low control low feedback n=56, high control high feedback n=83). We therefore continued random allocation until one experimental condition (high control, high feedback) reached the maximum sample size (n=92), which was at 82.9% of the overall intended sample size. After this we manually set the experiment code to a given condition to "fill" the remainder of the conditions. This is a slight deviation from the pre-registration that stated checking the condition allocations at 75% and 90% of the data collection. After extracting the data, 57 participants (15.5%) were to be excluded from the grid task analyses due to pre-registered exclusion criteria (i.e. failing to respond, failing attention checks). There were no significant differences in the condition these excluded participants had been allocated to ($\chi^2(3) = 1.56$, $p = .669$). We therefore continued to oversample to obtain n=368 (n=92 per group) who would be included in the grid task analyses, resulting in a total sample size of 436 for Study 2.

Materials

Software

The experiments were programmed using JavaScript and HTML, including plugins from jsPsych (Leeuw et al., 2023). The experiment was hosted online using Firebase (firebase.google.com).

Audio Checks

Study 2 began with a 3-minute headphone screening test previously validated for use in online studies (Milne et al., 2021). The test is based on a perceptual phenomenon, Huggins Pitch (HP), that can only be detected when stimuli are presented dichotically, e.g. via headphones, but not when listening over loudspeakers. Six trials were presented and the pass mark was 6/6. If participants failed the first time, they could complete a second attempt. If participants failed, the experiment ended and they were asked to return their submission on Prolific.

Participants also performed a pitch discrimination task, to ensure they could discriminate between high and low pitches, as this was used as an attention check for the grid task. Sine waves of the same frequencies as the high and low pitch screams were presented (low pitch: 1441.73 Hz; high pitch: 1950.58 Hz). Participants could play examples of each of the two tones as many times as they wanted to. Four trials were presented, playing two of each tone in a randomised order. Participants had to identify 3/4 trials correctly to pass and there was no second attempt. If participants did not pass, the experiment ended and they were asked to return their submission on Prolific.

Wheel Stopping Task

Control conditions. To induce high or low feelings of control we used two versions of the Wheel Stopping (WS) task in Study 1, but adapted to use just one version for both control conditions in Study 2. In the task there is a yellow segment that spins within a blue circle, and the participants' goal is to stop the yellow segment by pressing the 'b' key so that the segment stops over the red 'brake zone'. In Study 1, the two versions were a single-press and a multi-press version, while Study 2 only used the multi-press version. In the single-press version, one press of the brake causes the segment to stop. The stopping parameter is a stopping angle; for example, a stopping angle of $\pi/2$ means the segment stops a quarter of a rotation after the brake is pressed (since a whole rotation of the circle is 2π radians). For the multi-press version, pressing the brake increases the brake *strength* in an incremental way. The greater strength of the brake (here, how many times the 'b' key is pressed) the sooner it stops. The stopping parameter in the multi-press variation is called the deceleration increment. Previous work with 768 participants (Fielder et al., 2025) has shown these two task variations successfully induce either high feelings of control (single-press) or low control (multi-press). The speed and segment width of the wheel was also modulated to influence feelings of control. As well as a different braking procedure, the low control version therefore had higher speeds. For Study 2, only the multi-press version was used. This was to have an equivalent baseline block for all conditions prior to diverging into the high or low control condition, and to have the same experimental paradigm for both high and low control conditions for potential task-based analyses. The parameter combinations (speed, segment width, stopping parameter) were selected from pilot work to be neither too easy nor too difficult to maximise the believability of the rigged feedback (see below) given to participants. We selected 20 parameter combinations per WS task block (Table S1), to use for the 20 experimental blocks. The order in which the parameter combinations were presented was randomised across participants.

Social feedback conditions. To induce a self- or task-specific inference of control, pre-specified feedback was given to participants using social information of how they performed compared to other participants (e.g. "you performed in the bottom 10%"). Participants were told the feedback was relative to over 1,000 people who had previously taken part in this experiment, and based on an algorithm that considered several variables including successfully braking on the red brake zone but also the final proximity to the brake zone. There were two social feedback groups: participants either received low percentages of their performance relative to other participants (Low Social Feedback) or high percentages (High Social Feedback). Twenty random numbers between 2 and 55 were selected for the Low Social Feedback condition, and twenty random numbers between 45 and 98 for the High Social

Feedback condition (see Supplementary Information). The same 20 feedback amounts were used for all participants in that social feedback condition but were presented in a randomised order for each participant.

The 2x2 design (High or Low Control; High or Low Social Feedback) therefore produced four experimental conditions, outlined in Table . When the experience of control between oneself (performing the task) and feedback is congruent, the expected inference of control is self-specific. Where it is incongruent, the expected inference is task-specific.

Table 1

The four experimental conditions resulting from the 2x2 design: the participants' own experience of control playing the WS task (high or low control) and feedback given (high or other low), and the expected inferences of these conditions.

Experience of Control		**Expected Inference of Control**	
Task	Social Feedback		
High	High	Self-inference	***I am*** *highly in control*
Low	Low	Self-inference	***I am*** *barely in control*
High	Low	Task-inference	*This* ***environment*** *is highly controllable*
Low	High	Task-inference	*This* ***environment*** *is barely controllable*

Slider measures. During the WS task we collected subjective self-reports using visual-analogue scales. The first measured local control beliefs: "How in control do you feel right now?" from "very out of control" to "very in control"; one to assess their levels of stress: "How much stress are you currently experiencing?” from “very little stress” to “a lot of stress”; and one to measure perceived task difficulty: “How difficult are you finding the task right now?” from “not difficult at all” to “very difficult”. In Study 2, to measure participants’ attribution of control, we also asked two sliders, the first to measure their ability to control the wheel over the whole experiment: “Reflecting on the game overall, please rate your overall ability to control the wheel during the Wheel of Fortune” from “bad” to “good” followed by: “Why do you think that was?” from “because of the task” to “because of me”, to measure their attribution of control. We also asked these attribution questions after the baseline block to assess for any pre-existing group differences, in which the first question was adapted for baseline (i.e. not asking them to reflect on the game overall since they had only completed one block): “Please rate your overall ability to control the wheel during the task”. All slider responses corresponded to values 0-100, although numerals were not visible to participants. There was high internal consistency for the sliders (see Supplementary Information).

Grid Task (Study 2)

The grid task was adapted from a task by (Hartley et al., 2014). This task measures instrumental control learning and was considered suitable to assess the generalisation of previously acquired control beliefs to measure situational beliefs. A 5-by-5 grid with a purple outer edge was presented in the middle of the screen, with a red circle (the counter) in one of the squares. The counter always started on an edge, but never in a corner. Participants were instructed that they will be able to use the arrow keys on their computer keyboard to explore different actions during the grid trials. There were 18 trials and each trial was 6 seconds in duration. During each trial, a female scream was played. Participants could learn that moving the counter to the opposite side of the grid would terminate the scream. When the counter got to the opposite side, the outer edge of the grid would turn blue and the grid would freeze for the remainder of the trial duration to signal the desired state (counter on the opposite side of the grid). To ensure that participants did not mute their volume or take their headphones off, the screams were a higher or lower pitch which participants were asked to identify after the trial, used as an attention check. The scream was sound 277 from the IADS-2 database (Bradley & Lang, 2007) shortened to 1000ms and amplified by 15db (Morriss et al., 2015) chosen as an aversive stimulus based on recommendations for online testing due to its high ratings for unpleasantness and arousal (Seow & Hauser, 2022). We then used Audacity ® (version 3.3.1) (Audacity Team, 2023) to change the original frequency by an increase or decrease of 15% to create higher and lower pitch screams respectively (low pitch: 1441.73 Hz; high pitch: 1950.58 Hz). The scream repeated three times with a 1000ms gap in between. There were 18 trials that started with the counter in each of the 12 unique start positions (outer edge of grid but never a corner) with 6 randomly selected start positions to repeat. Every six trials had an equal number of high and low pitch screams (three of each) played in a randomised order. After the grid task was completed, participants were asked to describe the specific response, if any, that they performed to terminate (to stop) the screams, and were asked to rate how confident they were that their response was correct (0-100 slider). We defined grid-learners as those who successfully 'escaped' (i.e., shuttled to the other side to terminate the scream) on at least one third of trials, in line with the original version of this task (Hartley et al., 2014). We excluded participants from the grid task analyses who passed fewer than 12 of the 18 scream discrimination attention checks, as this indicated they did not have their audio on. See Supplementary Information for other pre-registered attention check and exclusion criteria.

Questionnaires

Locus of Control

To assess general beliefs about control in Study 1, participants completed the 29-item Locus of Control (LOC) questionnaire (Rotter, 1996), where higher scores indicate more external locus of control. Study 1 and 2 included a briefer 4-item measure, the Internal-

External-4 (IE4) questionnaire (Nießen et al., 2022) which gives scores for the two subscales of internal and external locus of control, respectively (mean of the 2 items per subscale). The different (sub)scales were used separately in subsequent analyses.

Mental Health

For Study 1, the State-Trait Anxiety Inventory (STAI) (Spielberger et al., 1999) was used to assess anxiety, which includes 20 items for the state subscale (STAI-S) and 20 for the trait subscale (STAI-T). For Study 2, we used the General Anxiety Disorder questionnaire (GAD-7) (Spitzer et al., 2006) to measure general anxiety symptoms and the Patient Health Questionnaire (PHQ-9) (Kroenke et al., 2001) to measure depressive symptoms. These differed in Study 2 based on recommendations of mental health metrics (Wellcome, 2020). Both studies included the 3-item mini Social Phobia Inventory (Connor et al., 2001).

Questionnaire Attention Checks

For the STAI and Locus of Control questionnaires (Study 1 only), attention checks were included (e.g. questions such as “select this option”, “I am paying attention and answering truthfully” included within the questionnaires). Three participants each failed one attention check (one LOC pre-task, and two STAI-T) and were given a missing value for the corresponding questionnaire.

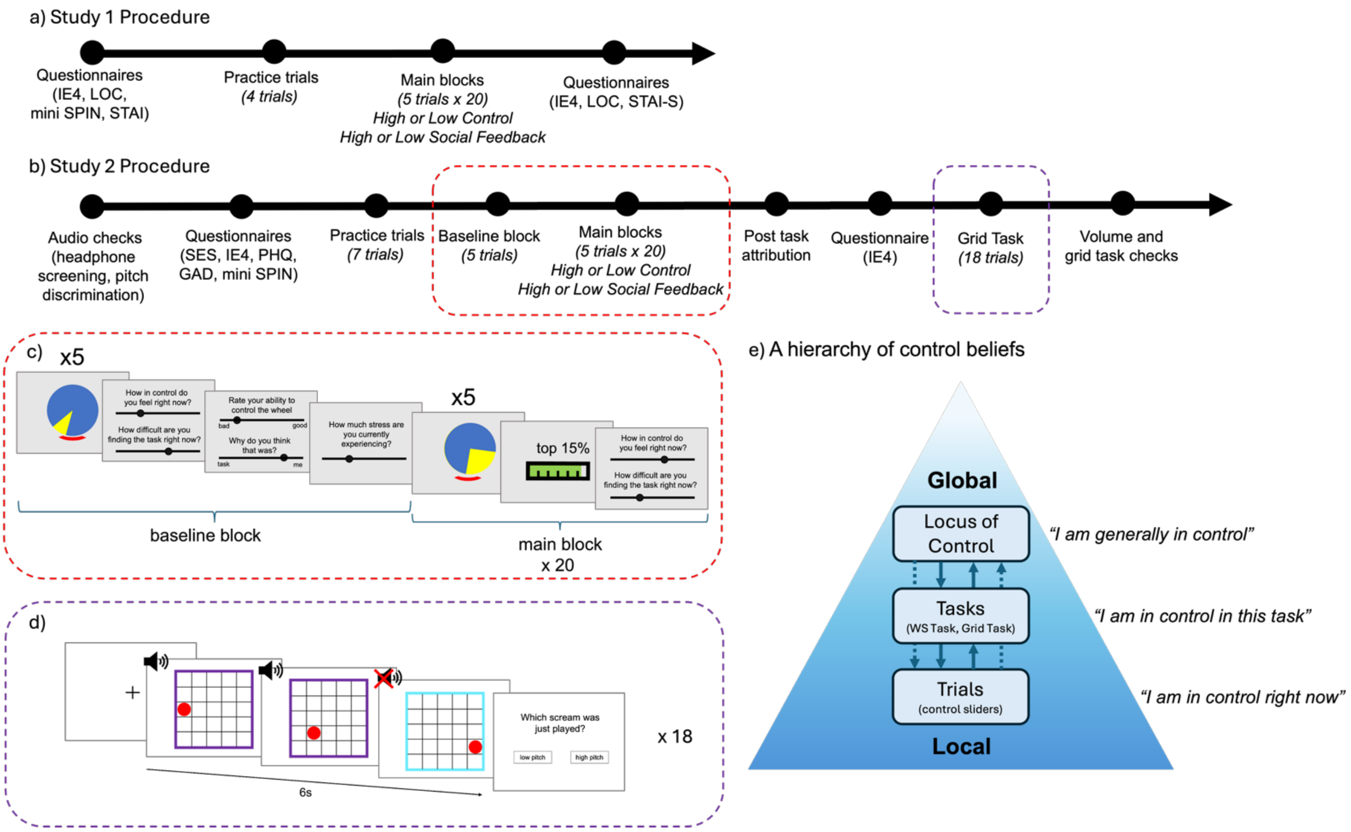
Procedure

After reading the information sheet and signing the electronic consent form, participants completed the questions/questionnaires in the following order: Study 1: IE4, LOC, mini-SPIN, STAI; Study 2: education level, MacArthur ladder, IE4, PHQ-9, GAD-7, mini-SPIN. Participants then completed the first stress slider. Participants were given instructions about how to play the Wheel Stopping task and were informed that they would earn an extra 1p for every successful trial where the segment lands over the red brake zone (Study 1) or would lose/keep their £3 bonus if a randomly selected trial was (in)correct (Study 2).

Participants completed 4 (Study 1) or 7 (Study 2) practice trials (no bonus). In Study 2 only, participants then moved on to a baseline block of 5 trials (all the same WS task parameters), followed by baseline slider measures of control, difficulty, attribution of control and stress. Participants were then allocated to one of four conditions (2x2 between-subjects design), either high or low control, and high or low performance feedback relative to others. The main trials consisted of 20 blocks each containing 5 trials. All trials within a block had the same parameters (speed, segment width, stopping parameter). In Study 1, control and difficulty sliders alternated after every block (therefore asked 10 times throughout the WS task), with control sliders asked after odd numbered blocks (1, 3, 5 etc) and difficulty sliders were asked after even numbered blocks, while in Study 2, both sliders were asked every block (after baseline block, then 20 times throughout the WS task). Stress sliders were asked after completing the questionnaires, after the baseline block (Study 2 only), and after every 5 blocks (4 times throughout the WS task). Participants were instructed when they were halfway through the WS task that they could take a short break. After all the WS trials, in Study 1 participants completed the following questionnaires in this order: IE4, LOC, STAI-S; while Study 2 participants completed the attribution sliders then completed the IE4. In Study 1, participants were then debriefed that the feedback provided was fabricated and the study ended. In Study 2, participants moved onto the grid task, were then asked the task check questions, and finally debriefed that the WS task feedback provided was fabricated. Figure 1 shows the procedure overview.

Figure 1

Task Procedure. a) procedure outline for Study 1, b) procedure outline for Study 2, c) simplified schematic of Wheel Stopping task baseline block from Study 2, then main blocks (either High or Low control, and High or Low social feedback). Self-reported stress was also measured after every 5 blocks (not shown), d) schematic of one grid task trial from Study 2, where arrow keys could move the red counter and would terminate the scream if it reached the opposite grid edge, e) hierarchy of control beliefs, figure inspired by (Seow et al., 2021, p. 440).



Data Availability and Analysis

De-identified data for both studies and analysis scripts are available on the Open Science Framework: https://osf.io/qp8zb/ (Fielder & Steinbeis, 2025). Statistical analyses were performed in R version 4.4.1 (R Core Team, 2024), including packages "lme4" (Bates et al., 2015) for the mixed effects models, and "tidyverse" (Wickham et al., 2019) for data wrangling and plots. Linear mixed effects models were fit by restricted maximum likelihood (REML) with *t*-tests using Satterthwaite's method, and standardised beta coefficients (β) are reported using a refit method for standardisation. For Study 1, since control and difficulty sliders were presented after alternate blocks, they were aligned for the linear mixed effects models such that the first control slider (after Block 1) was at the same 'timepoint' as the first difficulty slider (after Block 2), and so on. Changes from before to after the task (such as changes in global control beliefs) were assessed using a mixed ANOVA. The dependent variable was the variable of interest (e.g. locus of control measure), with control condition and social feedback condition as between-subjects factors and timepoint (pre- or post-task) as the within-subjects factor. Internal consistency for the slider measures used the R package "irr" (Gamer et al., 2019). For post-hoc analyses following significant interactions from linear mixed effects models, estimated marginal means were investigated using the "emmeans" package (Lenth, 2022) using Kenward-Roger degrees-of-freedom method. We corrected for multiple comparisons using Benjamini-Hochberg (False Discovery Rate) procedure (reported as adjusted p values, p_{adj}). When manually adjusting p values (outside of inbuilt function options), we input the values to be corrected into the "p.adjust" R function. In the instance that initial unadjusted p values were non-exact (e.g. <0.0001), we used the upper limit as the estimate (e.g. 0.0001) for adjustment. Effect sizes (η_p^2 , Cohen's f^2 and Cohen's repeated measures d) are calculated using the "effectsize" package (Ben-Shachar et al., 2020). Semi-partial (or 'part') R^2 is reported as the effect size for fixed effect predictors for linear mixed effects models, calculated using the "partR2" package and uses 25 bootstrap iterations for confidence interval estimation (Stoffel et al., 2024).

Results

Study 1

The four experimental groups differed in terms of age but no other variables (Table S2). Sensitivity analyses confirmed the age difference did not explain any of the results below (see Supplementary Information, Table S3).

Wheel Stopping Task - Wins

Participants won more trials in the high control (single-press) condition (mean=63.9, SD=13.90) than in the low control (multi-press) condition (mean=47.6, SD=8.61; main effect of control condition $F(1, 196)=99.3$, $p<.0001$, $\eta_p^2=0.34$ [95% CI 0.25, 1.00]). Furthermore, number of wins did not differ between social feedback conditions (main effect $F(1, 196)=0.025$ $p=0.874$, $\eta_p^2<0.001$ [95% CI 0.00, 1.00] and no interaction effect with control $F(1, 196)=0.536$, $p=0.465$, $\eta_p^2<0.001$ [95% CI 0.00, 1.00]). Hence, performance was affected by the control condition, but not by the social feedback. Winning more trials was associated with lower perceived difficulty ratings ($\beta=-0.44$, $p<.001$), but task performance was affected by the control condition over and above perceived difficulty ($\beta=-0.98$, $p<.001$).

Local Control Beliefs

To test how the social feedback and control conditions affected local control beliefs (subjective experience of control during the task), a linear mixed effects model was fit to the data (Table S4), predicting local control beliefs from the fixed effects of control condition, social feedback, and their interaction. Perceived difficulty was included as a covariate. We allowed for random effects of participant and timepoints. As expected, being in the low control condition predicted lower local control beliefs ($\beta=-0.48$, $p=.001$, part $R^2=0.074$ [95% CI 0.025, 0.124]), as did perceiving the task as more difficult ($\beta=-0.19$, $p<.001$, part $R^2=0.037$ [95% CI 0.002, 0.088]). Social feedback also had a significant impact on participants' local control beliefs, whereby low social feedback led to lower local control beliefs than high social feedback ($\beta=-0.28$, $p=.039$, part $R^2=0.023$ [95% CI 0.000, 0.073]). We found that the self-inference of control conditions (*oneself* in / out of control) led to more pronounced local control beliefs (higher or lower, respectively) than the task-inference of control, even when accounting for perceived task difficulty (Figure 2). This pattern indicates that socially informed inferences of control inform local control beliefs. There was no interaction between control condition and social feedback (β=1.96, p=.704, part R^2=0.000 [95% CI 0.000, 0.067]).

Global Control Beliefs (Locus of Control)

We also tested whether the social feedback impacted global control beliefs, such as changes to locus of control from pre-task to post-task. Our main effect of interest was whether the experimental conditions (control and social feedback) had significant interactions with timepoint, suggesting that locus of control after the task was influenced by the different inferences of control probed by the experiment. Changes in IE4-External from pre-task to post-task were dependent on the control and social feedback condition (Figure S3; significant interaction between control and social feedback condition $F(1,196)$=7.079, p=.008, η_p^2=0.035; and a significant three-way interaction between control, social feedback and time $F(1,196)$=6.601, p=.011, η_p^2=0.033). We did not see a significant interaction of control and social feedback with time using Rotter's LOC or IE4-Internal (see Supplementary Information). Post-hoc pairwise comparisons of the individual conditions suggested that this effect was driven by the low control and low social feedback group, who showed a marginal increase from pre- to post-task ($t(49)$= -2.421, $p_{unadj.}$=0.019, $p_{adj.}$=0.077, Cohen's d_{rm} = 0.27 [95% CI 0.06, 0.63]), while the other three conditions did not show a change in scores (high control, low social feedback: $t(49)$=-0.172, $p_{unadj.}$=0.864, $p_{adj.}$=0.864; high control, high social feedback: $t(49)$=-1.071, $p_{unadj.}$=0.290, $p_{adj.}$=0.386; low control, high social feedback: ($t(49)$=1.176, $p_{unadj.}$=0.245, $p_{adj.}$=0.386).

Study 1 hence suggests that comparative social information impacts local control beliefs, and may underpin generalisation to global control beliefs. We therefore sought to replicate this in a separate, larger sample (Study 2). For Study 2 we additionally included a WS task baseline block prior to receiving any social feedback and adapted the high control condition to the multi-press paradigm (with easier wheel parameters than the low control condition) to ensure all participants received the same task and parameters in the baseline block. We also measured local control beliefs and perceived difficulty at all the same timepoints (rather than alternating as in Study 1) to better statistically isolate local control beliefs from perceived difficulty, and measured perceived attribution of control (self- or task-inference) at the end of the WS task to assess situational (i.e. task-level) control beliefs and attribution. Furthermore, to test whether socially informed inferences of control from the WS task generalise to impact performance in a second task, we added a second stressor controllability task after the WS task in Study 2.

Study 2

There were no pre-existing group differences in demographic or questionnaire measures across the social feedback and control groups (Table S6), so these were not added as co-variates to subsequent analyses.

Wheel Stopping Task - Wins

We assessed number of WS task wins during the baseline block, during which all groups performed the same task (multi-press with same parameters). At baseline, a 2-way ANOVA showed a main effect of social feedback ($F(1, 432)=6.66$, $p=.010$, $\eta_p^2=0.02$), but not of control condition ($F(1, 432)=0.245$, $p=.621$, $\eta^2<0.001$) nor an interaction between control and social feedback ($F(1, 432)=0.000$, $p=.999$, $\eta_p^2<0.001$). The groups allocated to the high social feedback conditions won, on average, a greater number of the baseline trials (mean=2.83, SD=1.40) than the low social feedback conditions (mean=2.48, SD=1.41), despite no social feedback being given at this stage.

We then investigated the effects of control and social feedback conditions on the number of wins in the main WS task, when controlling for baseline number of wins (to account for pre-existing differences in task performance). There was a large effect of control condition on main task wins (β=-1.39, p<.0001, Cohen's f^2 = 0.67 [95% CI 0.53, inf]) with fewer wins in low control (mean=49.5, SD=9.56) than high control (mean=68.9, SD=14.6), as expected (see also Study 1), as well as a small but significant effect of number of baseline wins predicting main task number of wins (β=0.19, p<.0001, Cohen's f^2 = 0.06 [95% CI 0.03, inf]). Unlike Study 1, there was a significant, albeit very small, main effect of social feedback (β=-0.28, p=.006, Cohen's f^2 = 0.01 [95% CI 0.00 inf]) where low social feedback was associated with worse task performance, as well as a significant interaction between control and social feedback (β=0.29, p=.046, Cohen's f^2 <.001 [95% CI 0.00, inf]), such that receiving high feedback increased the number of wins more in the high control condition (β= 4.40, SE=1.61, $t(431)$=2.74, $p_{adj.}$=.013) but not in low control conditions (β= -0.18, SE=1.64, $t(431)$=-0.11, $p_{adj.}$=.913), after accounting for baseline performance. Rating the task as more difficult on average was associated with winning fewer trials (β=-0.32, p<.001, Cohen's f^2 = 0.16 [95% CI 0.10 inf]), but control condition still uniquely predicted the number of wins (β=-1.17, p<.0001, Cohen's f^2 = 0.78 [95% CI 0.62, inf]) over and above perceived difficulty and baseline number of wins (β=0.14, p<.0001, Cohen's f^2 = 0.07 [95% CI 0.04, inf]. After accounting for perceived difficulty, there was no main effect of social feedback (β=-0.16, p=.106, Cohen's f^2 = 0.02 [95% CI 0.00 inf]) but a significant interaction between control and social feedback (β=0.28, p=.036, Cohen's f^2 = 0.01 [95% CI 0.00, inf]), though this interaction is likely due to small crossover effects, as there were no differences in the number of wins between the social feedback conditions in high control (β= 2.45, SE=1.51, $t(430)$=2.45, $p_{adj.}$=.192) or in low control (β= -2.01, SE=1.54, $t(430)$=-2.01, $p_{adj.}$=.192), after accounting for baseline performance and perceived difficulty. How the experimental conditions affected perceived difficulty and subjective stress ratings during the WS task can be found in the Supplementary Information. This suggests that, like Study 1, after accounting for perceived task difficulty, control condition strongly predicted task performance (number of wins) but the social feedback did not.

Local Control Beliefs

To test our first pre-registered hypothesis, we investigated how the social feedback and control conditions impacted local control beliefs during the task. A 2-way ANOVA showed there were no pre-existing differences in local control beliefs at baseline (control condition: $F(1, 432)=0.150$, $p=.699$, $\eta^2<0.001$, social feedback: $F(1, 432)=1.394$, $p=.239$, $\eta^2<0.001$, control and social feedback interaction: $F(1, 432)=0.463$, $p=.497$, $\eta^2=0.001$), and so baseline control ratings were not included as a covariate. We ran a linear mixed effects model predicting local control beliefs from the fixed effects of control, social feedback, and their interaction, while allowing for random effects of timepoint and participant. This showed a main effect of control condition, with low control predicting lower local control beliefs ($\beta=-0.54$, $p<.001$, part $R^2=0.063$ [95% CI 0.008, 0.116]), as expected, and a main effect of social feedback with low social feedback predicting lower local control beliefs ($\beta=-0.43$, $p<.001$, part $R^2=0.041$ [95% CI 0.000, 0.094]), but no interaction between control and social feedback ($\beta=0.02$, $p=0.882$, part $R^2=0.000$ [95% CI 0.000, 0.038]). Like Study 1, these main effects of control and social feedback conditions also held when including perceived task difficulty at each time point as a covariate (control: $\beta=-0.14$, $p=.026$, part $R^2=0.026$ [95% CI 0.007, 0.055]; social feedback $\beta=-0.18$, $p=.004$, part $R^2=0.026$ [95% CI 0.008, 0.055]). We also ran a model that included number of wins during the task to account for differences in task performance. The main effect of control condition was no longer significant ($\beta=0.03$, $p=.670$, part $R^2=0.000$ [95% CI 0.000, 0.037]), given that the control condition was associated strongly with task performance, but the main effect of social feedback still held ($\beta=-0.14$, $p=.022$, part $R^2=0.018$ [95% CI 0.000, 0.056]), showing that receiving social feedback impacted local control beliefs over and above actual task performance (Table). These directional main effects of control and feedback therefore replicate our findings from Study 1 and support our first pre-registered hypothesis, whereby socially informed inferences of control impact local control beliefs (see Figure 2).

Table 2

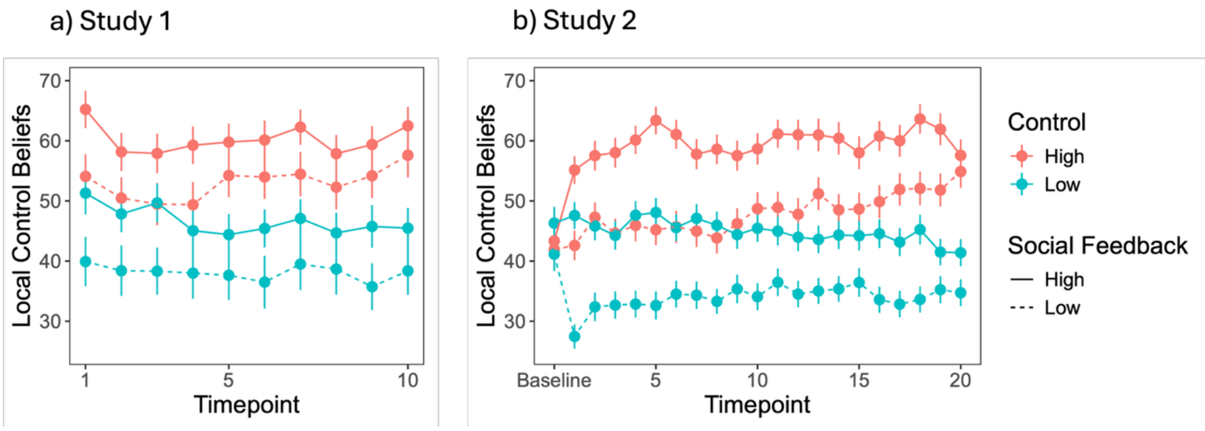
Linear mixed effects model predicting local control beliefs in Study 2, with no covariates (left), and with covariates (right).

	Local Control Beliefs (no covariates)							Local Control Beliefs (including WS task wins and difficulty)						
Predictors	*β*	*(95% CI)*	*SE β*	*t*	*p*	*part R^2*	*(95% CI)*	*β*	*(95% CI)*	*SE β*	*t*	*p*	*part R^2*	*(95% CI)*
(Intercept)	0.48	0.34 – 0.61	0.07	31.63	**<.001**			0.07	-0.03 – 0.16	0.05	19.93	**<.001**		
Control [Low]	-0.54	-0.74 – -0.35	0.10	-5.49	**<.001**	0.063	0.033 – 0.109	0.03	-0.11 – 0.18	0.07	0.43	.670	0.000	0.000 – 0.039
Social Feedback [Low]	-0.43	-0.62 – -0.24	0.10	-4.42	**<.001**	0.041	0.010 – 0.088	-0.14	-0.26 – -0.02	0.06	-2.28	**.022**	0.018	0.000 – 0.056
Control [Low] × Social Feedback [Low]	0.02	-0.25 – 0.29	0.14	0.15	.882	0.000	0.000 – 0.041	-0.04	-0.21 – 0.14	0.09	-0.41	.678	0.000	0.000 – 0.037
Overall WS task wins								0.13	0.07 – 0.18	0.03	4.51	**<.001**	0.042	0.005 – 0.080
Perceived Difficulty								-0.67	-0.69 – -0.66	0.01	-80.54	**<.001**	0.379	0.351 – 0.405
Random Effects														
σ^2	281.06							162.90						
τ_{00}	372.60 $_{ppt}$							146.47 $_{ppt}$						
	0.86 $_{timepoint}$							0.19 $_{timepoint}$						
ICC	0.57							0.47						

N	436 $_{ppt}$	436 $_{ppt}$
	20 $_{timepoint}$	20 $_{timepoint}$
Observations	8720	8720
Marginal R^2 / Conditional R^2	0.114 / 0.620	0.574 / 0.776

Figure 2

Mean local control beliefs (control slider responses) over the course of the experiment for a) Study 1 and b) Study 2. Study 2 included a baseline measure, and asked sliders every block rather than every-other.



Attribution of Control

We next turn to our second pre-registered hypothesis, assessing how control and social feedback conditions designed to change the self- or task-specific inference of control affected the control attribution made after the WS task. This was based on the sliders assessing participants' subjective ratings of their ability to control the wheel (from bad to good) and the attribution of why this was (because of the task or self) in the analyses, considering these two sliders as dependent variables together. We initially assessed for group differences of attribution after the baseline block with a MANOVA, with ability and attribution as the two dependent variables and control and social feedback (and their interaction) as independent variables. This revealed significant pre-existing differences of a small effect-size at baseline due to social feedback condition (Pillai's Trace = 0.0138, $F(2, 431) = 3.024$, $p = .0496$, $\eta_p^2=0.01$), and marginally because of control condition (Pillai's Trace = 0.0178, $F(2, 431) = 2.983$, $p = .0517$, $\eta_p^2=0.01$), but not due to an interaction of control and social feedback conditions (Pillai's Trace = 0.001, $F(2, 431) = 0.268$, $p = .765$, $\eta_p^2=0.001$).

To assess post-task attribution, we therefore included baseline ability and attribution ratings as co-variates, and conducted a MANCOVA with post-task ability and attribution as the two dependent variables, and control and social feedback (and their interaction) as the independent variables. This revealed main effects of control (Pillai's Trace = 0.168, $F(2, 429) = 43.30$, $p < .001$, $\eta_p^2 = 0.17$) and social feedback (Pillai's Trace = 0.202, $F(2, 429) = 54.46$, $p < .001$, $\eta_p^2 = 0.20$), but no interaction between control and social feedback (Pillai's Trace = 0.008, $F(2, 429) = 1.78$, $p = .170$, $\eta_p^2 = 0.008$). The co-variates were significant predictors as expected (baseline ability: Pillai's Trace = 0.241, $F(2, 429) = 68.09$, $p < .001$, $\eta_p^2 = 0.24$; baseline attribution: Pillai's Trace = 0.287, $F(2, 429) = 86.46$, $p < .001$, $\eta_p^2 = 0.29$). Though not pre-registered, to test whether one of the dependent variables was driving this effect, we conducted univariate follow tests on each dependent variable separately (ANCOVA), to assess whether the main effects of control and social feedback from the MANCOVA were influencing the ability or attribution ratings differently. For the post-task ability rating, there were main effects of control ($F(1, 430)=86.61$, $p<0.001$, $\eta_p^2=0.17$) and social feedback ($F(1, 430)=109.17$, $p<0.001$, $\eta_p^2=0.20$) but no interaction ($F(1, 430)=0.004$, $p=.952$, $\eta_p^2<0.001$), after accounting for the baseline covariates. For the post-task attribution rating, there were no main effects of control ($F(1, 430)=0.790$, $p=.375$, $\eta_p^2=0.002$) or social feedback ($F(1, 430)=2.06$, $p=.152$, $\eta_p^2=0.005$), and only a trend interaction ($F(1, 430)=3.454$, $p=.064$, $\eta_p^2=0.008$). Figure 3a shows the change (post-task minus pre-task) for control attribution of the different groups. Overall, these results indicate that the control and social feedback conditions changed participants' belief of their ability to control the wheel, similar to the change in local control beliefs seen in our first hypothesis, but participants did not explicitly rate this ability as being more self or task specific.

Grid Task Performance

To test our third pre-registered hypothesis, we investigated whether the control and social feedback conditions impacted measures of task behaviour in a second task, the grid task, which would indicate generalisation across tasks. As pre-registered, we assessed two outcome measures from the grid task: the proportion of grid learners per group (successful on at least one third of trials), and path length (how many moves made) on successful trials. We predicted that the self-specific high control condition would show superior performance (higher proportion of grid learners and lower mean path length) than the task-specific high control task-specific inference, which would show better performance than low control conditions, in which the self-inference low control condition would show the worst performance. There were 242 (65.8%) grid learners overall, and the proportion was similar across the four experimental conditions (Figure 3b). A logistic regression confirmed there was no main effect of control (B=-0.05, SE=0.311, p=.877, OR = 0.95 [95% CI 1.29, 3.09]) or social feedback (B=0.099, SE=0.315, p=.753, OR = 1.10 [95% CI 0.60, 2.05]), nor an interaction (B=-0.193, SE=0.440, p=.660, OR = 0.82 [95% CI 0.35, 1.95]) when predicting the likelihood of being classified as a grid learner or not. Our second pre-registered outcome measure for hypothesis 3 was to assess the mean path length on successful trials (calculated per participant), where a shorter path length indicates more efficient behaviour in the grid task with the minimum number of moves being four. A 2-way ANOVA revealed a main effect of social feedback ($F(1, 262)=4.799$, $p=.029$, $\eta_p^2=0.02$), but not of control ($F(1, 262)=0.010$, $p=.921$, $\eta_p^2<0.001$) nor an interaction ($F(1, 262)=0.126$, $p=.723$, $\eta_p^2<0.001$). Contrary to predictions, the low social feedback groups had a lower mean path length (mean = 6.23, SD=1.72) than the high social feedback groups (mean = 6.80, SD=2.48) ($t(235.2)=-2.20$, $p=.029$, Cohen's d = 0.27) (Figure 3c). As seen in Figure 3c, one participant in the high control, high social feedback group had a mean path length on successful trials of 16.94. A sensitivity analysis confirmed that the low social feedback groups still had a lower mean path length on successful trials when excluding this participant as a potential outlier ($t(241.37)=-1.985$, $p=.048$, Cohen's $d = 0.24$). Overall, our third hypothesis was not supported, as the control and social feedback groups designed to change self- and task-specific attributions of control led to no differences in task performance in the grid task.

Global Control Beliefs (Locus of Control)

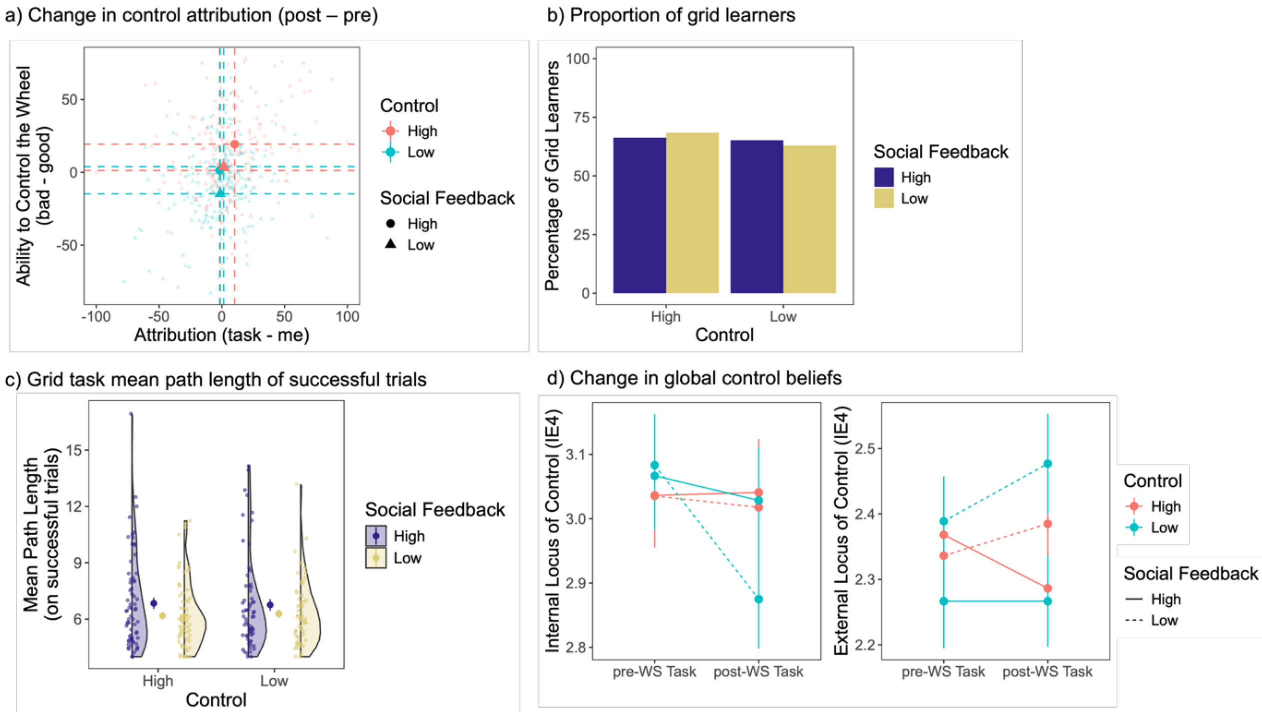
As exploratory analyses (not pre-registered), we assessed how control and social feedback conditions designed to change the self- or task-specific inference of control affected global control beliefs (locus of control). A change from pre-task to post-task would indicate that socially informed inferences of control generalise to global control beliefs. The dependent variable was the locus of control measure (IE4 Internal or External), with control and social feedback as between-subjects factors and timepoint (pre- or post-task) as the within-subjects factor. Our main effect of interest was whether the experimental conditions (control and social feedback) had a significant interaction with timepoint, suggesting that locus of control after the task was influenced by the different inferences of control probed by the experiment. For internal locus of control (IE4-Internal) there was a significant main effect of time ($F(1,432)=8.38$, $p=.004$, $\eta_p^2=0.019$) as well as significant two-way interactions between control and time $F(1,432)=6.77$, $p=.01$, $\eta_p^2=0.015$), and between social feedback and time $F(1,432)=4.61$, $p=.032$, $\eta_p^2=0.011$), but no significant three-way interaction of control, social feedback, and time ($F(1,432)=2.72$, $p=.100$, $\eta_p^2=0.006$). This suggests that the changes in IE4-Internal from pre-task to post-task were dependent on control (at both levels of social feedback) and on social feedback (at both levels of control) (Figure 3d). Pairwise multiple comparisons comparing pre- and post-task scores (paired t-tests) revealed there was a significant decrease in internal locus of control in low control ($t(212)=3.70$, $p_{unadj.}<.001$, $p_{adj.}=0.001$, Cohen's $d_{\mathrm{rm}}=0.15$ [95% CI 0.07, 0.23]) but not high control $t(222)=0.223$, $p_{unadj.}=0.824$, $p_{adj.}=0.824$, Cohen's $d_{\mathrm{rm}}=0.000$ [95% CI -0.06, 0.08]). There was a significant decrease in internal locus of control in low social feedback ($t(220)=3.25$, $p_{unadj.}=.001$, $p_{adj.}=0.003$, Cohen's $d_{rm}=0.14$ [95% CI 0.05, 0.22]) but not in high social feedback $t(214)=0.551$, $p_{unadj.}=.582$, $p_{adj.}=0.777$, Cohen's $d_{rm}=0.02$ [95% CI -0.05, 0.09]). Although there was no significant three-way interaction in the main model, the two-way interactions seem driven by the low control, low social feedback group, as when comparing pre- and post-task internal locus of control scores in each of the four conditions separately, this is the only group where there was a significant difference from pre- to post-task (low control, low social feedback: $t(107)=4.05$, $p_{unadj.}<.001$, $p_{adj.}<.001$, Cohen's $d_{rm}=0.25$ [95% CI 0.13, 0.38]; low control, high social feedback: $t(104)=0.92$, $p_{unadj.}=.361$, $p_{adj.}=.723$, Cohen's $d_{rm}=0.04$ [95% CI -0.05, 0.14]; high control, low social feedback: $t(112)=0.41$, $p_{unadj.}=.685$, $p_{adj.}=.913$, Cohen's $d_{rm}=0.02$ [95% CI -0.08, 0.12]; high control, high social feedback: $t(109)=-0.11$, $p_{unadj.}=.914$, $p_{adj.}=.914$, Cohen's $d_{rm}=-0.005$ [95% CI -0.10, 0.09]) (Figure 3d).

For external locus of control (IE4-External), a mixed ANOVA revealed a significant two-way interaction of social feedback and time ($F(1,432)=4.79$, $p=.029$, $\eta_p^2=0.011$), but no two-way interaction of control and time ($F(1,432)=1.47$, $p=.226$, $\eta_p^2=0.011$), nor a three-way interaction of control, feedback and time ($F(1,432)=0.182$, $p=.670$, $\eta_p^2=0.003$). Post-hoc paired *t*-tests comparing pre- to post-task IE4-External showed no change in external locus of control at low social feedback ($t(220)=-1.88$, $p_{unadj.}=.062$, $p_{adj.}=0.123$, Cohen's $d_{rm}=-0.09$ [95% CI -0.18, 0.00]) or high social feedback ($t(214)=1.22$, $p_{unadj.}=.224$, $p_{adj.}=0.224$, Cohen's $d_{rm}=0.05$ [95% CI -0.03, 0.14]), and the two-way interaction is likely significant due to cross-over effects (Figure 3d).

Overall, this suggests that the inferences from the low control low social feedback condition impacted global control beliefs as indicated by a decrease in internal locus of control. Interestingly, this is the same group that showed a tentative *increase* in external locus of control in Study 1.

Figure 3

a) Changes in control attribution (post-task minus pre-task) across the 4 different groups. The only significant differences dependent on control and social feedback conditions were on the ability axis (y-axis). b) The proportion of grid learners across the different groups where there were no significant differences. c) the mean path length on successful trials during the grid task, where the low feedback conditions had overall a shorter path length. d) Internal (left) and external (right) locus of control scores pre- and post-WS task. The low control, low social feedback group significantly decreased in internal locus of control over time.



Robustness Checks

Across both studies we found local control beliefs and subjective stress to be robustly associated with mental health and locus of control, replicating prior work (Fielder et al., 2025) (see Supplementary Information, Tables S8-11). We also assessed the external validity of our control attribution measure used in Study 2 and found that higher internal locus of control was associated with rating greater ability to control the wheel and greater self-attribution at baseline, as expected (see Supplementary Information). Finally, to assess the reliability of our pre-registered criteria of being a grid-learner (successfully escaping on at least one third of trials) we analysed participants' time to escape each trial across the duration of the experiment as well as the free-text responses of the action performed to terminate the scream, which indicated that grid-learners indeed learned to escape the grid while non-learners had not (see Supplementary Information).

Discussion

Here we present two well-powered studies designed to test whether socially informed inferences about oneself or the environment are a potential mechanism for the generalisation of control beliefs. We used a novel task where subjective control was parametrically modulated to be higher or lower, and provided social feedback about task performance relative to others to inform participants about their level of control compared to others. We tested whether such social feedback influenced local and global control beliefs, and in Study 2, whether this impacted explicit attribution of control and generalised to influence performance in another task. We found that socially informed inferences of control informed local, situational, and global control beliefs, as measured by estimates of their subjective control at the experimental block-level, control beliefs regarding the whole experiment, and locus of control beliefs, respectively. However, these inferences did not change explicit attribution of control in the task, nor did the inferences relate to differences of performance in a second, different task. This demonstrates that socially informed inferences of control impact control beliefs at local to global levels, but do not, at least in this case, generalise to performance in a novel task.

In both studies, and confirming our first pre-registered hypothesis, socially derived inferences of control informed local control beliefs. Thus, in high control scenarios, the self-inference condition (i.e. *"I am highly in control"*) had higher sense of control than the task-inference condition (i.e. *"this task is controllable"*), while in low control scenarios, the self-inference condition (i.e. *"I am barely in control"*) had lower sense of control than the task-inference condition (i.e. *"this task is uncontrollable"*). Self-related inferences led to the most extreme shifts in control beliefs. Furthermore, when participants were asked at the end of the task to reflect on the whole experiment and rate their overall ability to control the wheel, socially derived inferences of control informed these situational beliefs similarly to the local beliefs. Our findings are consistent with prior research that external performance feedback can impact self-beliefs in different domains. For instance, recent work has found that providing external (non-social) feedback on performance shaped individuals' global self-performance estimates (an estimate of how many of the last 40 trials were correct), such that positive feedback increased confidence and negative feedback decreased confidence, despite actual task performance remaining the same (Katyal et al., 2025). Zacharopoulos et al. (2014) successfully manipulated self-efficacy by providing rigged social-comparative performance feedback (participants doing better or worse than others) and fictional research findings (that task performance was malleable and could be improved with practice, or that ability does not change), which either increased or lowered self-efficacy. By combining our social feedback manipulation with task difficulty, we were able to elicit greater shifts in control beliefs in conditions designed to elicit self-related inferences. This demonstrates that our manipulations were effective and that our paradigm is suited to testing the hypothesis that self-related inferences are a viable mechanism for generalising experiences of control (Moscarello & Hartley, 2017).

We find evidence that socially informed inferences of control changed our global measure of control beliefs, locus of control. This was specific to the low control condition, where we found that a self-inference of low control (i.e. *"I am barely in control"*) led to a tentative increase in external locus of control in Study 1 and a decrease in internal locus of control in Study 2. This reflects a change of global beliefs that things are more outside of your control (or less within your control). While locus of control has been found to be relatively stable (Hovenkamp-Hermelink et al., 2019), there is evidence of locus of control shifting, for example following an intervention such as cognitive behavioural therapy (Page & Hooke, 2003), temporarily due to job loss (Preuss & Hennecke, 2018), receiving earnings subsidies to work (Gottschalk, 2005), and retirement (Clark & Zhu, 2024), though such evidence is from higher intensity events, so it is striking that we see a change in our relatively short 30-minute study. We only see changes in locus of control from a self-inference of low control, and do not see the opposite pattern of results in high control. Research on social comparison distinguishes upward comparison, where others are considered better off, from downward comparison, where others are considered worse off (Bandura, 1991; Taylor, 1983; Wills, 1981). Here, our low social feedback condition is akin to upward comparison. Crucially, research has found different outcomes of social comparison depend on a situation's controllability. For example, upward comparison (low social feedback) has been found to be "debilitating" if accompanied by low perceived control, while downward comparison information (high social feedback) was found to prevent negative effects of low perceived control (Testa & Major, 1990). Similarly, downward comparison (high social feedback) has been linked to greater well-being in older adults when used in low control scenarios, but had no effect on well-being when used in high control scenarios (Stewart et al., 2013). In the current study, social feedback did not change locus of control in high control scenarios, but within the low control conditions, low social feedback was detrimental (e.g. decrease of internal locus of control) while high social feedback appears protective (e.g. no decrease of internal locus of control), consistent with previous research.

The change of local and global control beliefs seen in the present study is important to consider in the context of mental health. According to the cognitive model of psychopathology, the main factor responsible for the emergence and persistence of mental illness is maladaptive thoughts, beliefs, and information-processing patterns (Beck et al., 2024). Automatic thoughts or interpretations of events (e.g. *"she hates me"*) are guided by more stable and permanent beliefs, such as conditional rules and assumptions (e.g. *"if someone disagrees with me it means they do not like me"*) and core beliefs (e.g. *"I'm incompetent"*) (Arntz, 2018; Dobson & Shaw, 1986; Grodniewicz, 2024). Indeed, the purpose of cognitive restructuring (a component of cognitive behavioural therapy) is to train individuals to identify maladaptive cognitions and practice consideration of alternative explanations to ultimately revise beliefs (Beck, 1996; Beck et al., 2024). There is evidence that control beliefs specifically are related to mental health outcomes, such as greater external locus of control and depression and anxiety (Benassi et al., 1988; Culpin et al., 2015; Di Pentima et al., 2019; Presson & Benassi, 1996), and greater internal locus of control and resilience (de Quadros-Wander et al., 2014; Krampe et al., 2021; Yang & Ma, 2020). Given the current finding that social information shapes both local and global control beliefs, it is important to consider that, regardless of the actual task performed (i.e. event experienced), receiving high relative social feedback (e.g. downward comparison) may be a protective mechanism for mental health resilience while low relative social feedback (e.g. upward comparison) may be detrimental via the shaping of control beliefs. Future work should investigate these effects in samples highly sensitive to social feedback such as adolescents (Somerville, 2013; Towner et al., 2023), especially given adolescence is a sensitive period for the onset of mental illness (Blakemore, 2019).

Although we find evidence that socially informed inferences of control shape local and global control beliefs, in Study 2 we did not find any evidence that participants explicitly rated their control as being due to themselves (self-inference) or the task (environment-inference) differently depending on these inferences, thus failing to support our second pre-registered hypothesis. Furthermore, we found that the socially informed inferences of control during the first task (WS task) did not generalise to influence performance during a subsequent stressor controllability task (the grid task), thus failing to support our third pre-registered hypothesis.

While we designed the comparative social feedback of task performance to provide information about whether controllability is a generic feature of a given environment (i.e. where everyone has / does not have control) or specific to oneself (i.e. only I do / do not have control), our results suggest this did not change participants beliefs about the attribution of control as self or task specific. The changes in control beliefs at local and global levels may therefore simply reflect differences in the *amount* of subjective control participants believe to have, but not necessarily *why*. Given that participants' attribution of control did not change, this may explain the lack of generalisation to the second task, given that internal attributions (self) predict greater generalisation of learned helplessness behaviour (Glass et al., 1973; Miller & Seligman, 1975). Another possibility is that the social information did change attributions of control as intended, but our measure was not sensitive enough to detect this. To measure control attribution, we asked participants to rate their ability to control the wheel over the whole experiment, which reflected situational control beliefs, but crucially to rate *why* this was the case, on a scale from "task" to "me". This continuous scale was chosen to capture differences in the degree to which participants may attribute their control. There was indeed substantial variation post-task in the "task" to "me" attribution scale (the full range reported was from 0 to 100, mean = 58.0, SD = 26.2), but participants scores from pre- to post-task on average changed very little (range from -100 to 100, mean change = 2.2, SD = 25.3). At baseline we found higher internal locus of control scores predicted greater ability and self-attribution ratings, highlighting the external validity of this measure to capture attribution of control, but it is it possible this measure captures more general tendencies and not be sensitive to task-level changes. Another reason we did not see generalisation to a second task could be the context being too different. While we chose a stressor controllability task, it differed substantially to the WS task. The grid task included distressing audio and a pitch discrimination task, there was no monetary bonus at stake, and performance feedback was not provided during the task. Contextual factors play a significant role on the number and kind of beliefs that become readily accessible in the moment (Ajzen & Dasgupta, 2015; Ajzen & Sexton, 1999; Eitam & Higgins, 2010; Schwarz, 1999). Future work may wish to focus on testing boundary conditions on contextual difference when examining effects of generalisation. Our findings do show however that generalisation seems to occur at the level of control beliefs but not performance.

Constraints on Generality

We collected data online to obtain a large sample in a timely manner. We constrained the sample to UK residents due to ethics agreements, and 18-35-year-olds to limit any potential age-related differences in task performance. Thus, generalising our results to older participants or those outside the UK is cautioned, especially given that culture (Cheng et al., 2013) and age (Lumpkin, 1986) may be related to locus of control. The majority of our sample identified as White (68.3%, Study 2 data only). Although this is lower than the UK 2021 Census (81.7%) (Office for National Statistics, 2022), it may impact the generalisation of our findings to more ethnically diverse samples given that ethnicity has been found to relate to locus of control (Fiori et al., 2006; Zahodne et al., 2015). On average, our sample were above 'mild' severity cut-offs for both depression and anxiety symptoms (PHQ-9 mean = 6.74, SD = 5.32; GAD-7 mean = 5.39, SD = 4.73), and were roughly in the 85th percentile for PHQ-9 and GAD-7 scores compared to normative data from the general population in Germany (Kliem et al., 2025; Kocalevent et al., 2013) (UK normative data not found). While our sample included participants scoring the full range of possible scores on both questionnaires, the overall mild symptom severity average may impact the generalisation of our findings to samples with either minimal, or moderate to severe symptom severity.

Strengths and Limitations

Our study has notable strengths and limitations. A limitation of the study is that we did not systematically measure how believable participants found the social feedback. The WS task parameters (speed, segment size, deceleration) were chosen based on pilot data to limit floor or ceiling effects in performance, but it was possible for a participant to complete 5 correct trails and be given a low percentile, or fail 5 trials and be given a high percentile, potentially limiting the believability of the social feedback. To counter this, we told participants the performance was based on a complex algorithm that considered multiple factors (to avoid it seeming just based on wins or losses). Future work could create a more dynamic experimental paradigm, where the WS task parameters are adjusted using a staircase procedure for each participant to maintain a certain level of performance across all participants, with social feedback percentiles being drawn from a set distribution (i.e. generally good or generally bad) but selected based on the participant's performance within that block (i.e. at the higher end of the range if they won all the trials). Future research could also look at the expectation of social feedback dependent on performance, to investigate how the expectancy relates to changes in self-beliefs, similar to previous work in dynamic fluctuations of self-esteem (Will et al., 2017). Another limitation with our experimental paradigm is that we cannot assess the generalisation of control beliefs, only of task performance as a proxy for situational control beliefs. We did not include control rating sliders during the grid task to avoid priming participants that it might be controllable if they otherwise were not attempting to escape the grid. However, future work could test whether adding such a slider effects task performance, and if not, measure local control beliefs during a second task to assess whether self-beliefs generalise (e.g. Katyal et al., 2025). A strength of our paradigm is that the WS task was parametrically modulated to change *subjective* control, rather than considering control as just escapable/inescapable. This enabled a more fine-grained approach to manipulating and measuring control beliefs, including assessments at a local level at multiple timepoints throughout the WS task. A second strength is that our pre-registered second study had a well powered sample, and the replicated results of social feedback shaping local control beliefs in Study 2 highlights the robustness of this finding.

Conclusions

Overall, we found that socially informed inferences of control shaped local, situational, and global control beliefs, but these inferences did not change explicit attribution of control in the task as being due to themselves or the task, nor did they relate to differences of performance in a second, different task. Future work may wish to focus on the stability and longevity of such shifts and explore potential implications for well-being given the foundational role of control beliefs in mental health. Thus, it appears that socially informed inferences of control impact control beliefs at local to global levels, but did not underpin generalisation to influence performance in a new task.

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Supplementary Information

Table S1

The experimental parameters for the WS task conditions.

	Study 1 High Control (single-press)			Study 2 High Control (multi-press)			Both Studies Low Control (multi-press)		
Combination	Segment Width	Speed	Stopping Angle	Segment Width	Speed	Deceleration Increment	Segment Width	Speed	Deceleration Increment
1	2.513	0.12	2.513	2.513	0.09	0.0014	2.513	0.30	0.0002
2	2.513	0.10	2.513	2.513	0.09	0.0010	2.513	0.30	0.0008
3	1.885	0.12	2.513	2.513	0.10	0.0014	2.513	0.20	0.0002
4	1.885	0.10	2.513	2.513	0.09	0.0012	2.513	0.20	0.0004
5	1.885	0.08	2.513	2.513	0.12	0.0016	2.513	0.20	0.0008
6	1.885	0.06	2.513	2.513	0.15	0.0010	2.513	0.15	0.0002
7	1.257	0.12	2.513	2.513	0.15	0.0008	2.513	0.15	0.0006
8	1.257	0.12	1.257	1.885	0.07	0.0009	1.885	0.30	0.0004
9	1.257	0.10	2.513	1.885	0.08	0.0008	1.885	0.25	0.0002
10	1.257	0.08	2.513	1.885	0.08	0.0012	1.885	0.25	0.0006
11	1.257	0.06	2.513	1.885	0.09	0.0012	1.885	0.20	0.0002
12	0.628	0.12	2.513	1.885	0.08	0.0009	1.885	0.20	0.0008
13	0.628	0.12	1.257	1.885	0.12	0.0012	1.885	0.15	0.0002
14	0.628	0.12	0.628	1.885	0.13	0.0011	1.885	0.15	0.0004
15	0.628	0.12	0.314	1.257	0.07	0.0010	1.885	0.15	0.0006
16	0.628	0.10	2.513	1.257	0.08	0.0012	1.257	0.25	0.0006
17	0.628	0.10	1.257	1.257	0.08	0.0010	1.257	0.20	0.0004
18	0.628	0.08	1.257	1.257	0.09	0.0012	1.257	0.20	0.0006
19	0.628	0.06	2.513	1.257	0.08	0.0011	1.257	0.15	0.0004
20	0.628	0.06	1.257	1.257	0.09	0.0011	1.257	0.15	0.0006

Note: the order of block presentation was randomised across participants.

Social Feedback Percentages

Low percentages (random numbers between 2-55%) to indicate the participant's performance as worse than others':

4, 19, 11, 15, 39, 37, 28, 32, 5, 42, 37, 18, 53, 22, 31, 10, 49, 21, 41, 33

High percentages (random numbers between 45-98%) to indicate the participant's performance as better than others':

89, 77, 66, 97, 47, 67, 80, 81, 91, 71, 64, 97, 72, 90, 46, 51, 66, 91, 54, 88

Internal Consistency of Slider Measures

We estimated internal consistency for the slider scale ratings by calculating the intraclass correlation coefficient (ICC) between two halves of the data (here, using the mean of odd numbered sliders and the mean of the even numbered sliders as a two-way mixed effects model, single measurement type testing for absolute agreement, Koo & Li, 2016). There was high internal consistency for control ratings (Study 1: ICC(A,1) = 0.923 [95% CI: 0.900, 0.941], $F(199,198) = 25.3$, $p<.001$; Study 2: ICC(A,1) = 0.957 [95% CI: 0.948, 0.964], $F(435,435) = 45.3$, $p<.001$), difficulty ratings (Study 1: ICC(A,1) = 0.924 [95% CI: 0.899, 0.942], $F(199,166) = 26.0$, $p<.001$; Study 2: ICC(A,1) = 0.959 [95% CI: 0.951, 0.966], $F(435,436) = 47.6$, $p<.001$), and stress ratings (Study 1: ICC(A,1) = 0.893 [95% CI: 0.861, 0.918], $F(199,199) = 17.8$, $p<.001$; Study 2: ICC(A,1) = 0.912 [95% CI: 0.895, 0.927], F(435,436 = 21.7, $p<.001$).

Volume and Grid Task Checks

After the grid task (Study 2 only), the following four questions were asked: "Did you keep your headphones on for the entire duration of the grid task?" (yes/no), "Did you keep your volume on for the entire duration of the grid task?" (yes/no), "Did you keep your volume at the same level (set during the volume calibration) for the entire duration of the grid task?" (yes/no), and "If you did not use the arrow keys at all during the grid task, did you remember that you could use them to explore actions during the grid task?" (yes/no/NA (I used the arrow keys).

Grid Task Exclusion Criteria

As pre-registered and reported in the main text, we excluded participants from the grid task analyses who passed fewer than 2/3rds of the scream discrimination (12 of 18 trials) attention checks, as this indicates they did not have their audio on (given that all participants passed the initial pitch discrimination check at the start of the experiment). We also excluded participants who answered "no" to whether they kept their volume on for the entire duration of the grid task, as well as grid non-responders (those who did not move the counter at all during the grid task) who also answered "no" that they did not remember that they *could* use the arrow keys, as this indicates that they failed to remember the grid task instructions. These exclusions were for the grid task analyses only, and these participants were still included for the WS task analyses.

Socioeconomic Measures

In Study 2 we asked participants about their highest level of education completed on a 5-point scale: 1) No formal qualifications (e.g. primary school); 2) GCSEs, O-levels, NVO levels 1 & 2; 3) A-level, AS-levels, NVQ level 3, BTEC diplomas; 4) Undergraduate degree (BSc, BA) or equivalent (HND/HNC, City and Guilds Qualification, NVG level 4; 5) Postgraduate degree (MSc, MA, PhD) or professional qualification (e.g. law or accountancy training). We also presented the MacArthur 10-rung ladder to measure subjective socioeconomic status (Adler et al., 2000). The ladder was told to represent where people stand in UK society, with the top of the ladder being the people who are the best off, those who have the most money, most education, and best jobs. Participants were asked where they would place themselves on this ladder.

Table S2

Study 1 descriptive statistics across the 4 conditions. Group differences were assessed using a one-way ANOVA for continuous variables or a Chi-squared test for categorical variables.

Control	High Control		Low Control		Group Differences
Social Feedback	High	Low	High	Low	
Age – mean (SD)	27.22 (5.07)	26.82 (4.86)	28.64 (4.57)	29.88 (3.86)	F(3, 196) = 4.60, p = 0.004*
Female – n (%)	25 (50)	25 (50)	26 (52)	25 (50)	X(3, N=200) = 0.06, p = 0.996
Nationality UK – n (%)	41 (82)	43 (86)	44 (88)	47 (94)	X(3, N=200) = 3.43, p = 0.330
First language English – n (%)	45 (90)	41 (82)	47 (94)	47 (94)	X(3, N=200) = 5.33 p = 0.149
LOC (initial) – mean (SD)	15.44 (4.10)	15.22 (3.62)	14.44 (3.56)	13.76 (4.18)	F(3, 195) = 1.95, p = 0.122
IE4 Internal (initial) – mean (SD)	3.22 (0.91)	3.23 (0.79)	3.28 (0.76)	3.17 (0.77)	F(3, 196) = 0.16, p = 0.926
IE4 External (initial) – mean (SD)	2.32 (0.61)	2.21 (0.59)	2.23 (0.78)	2.43 (0.78)	F(3, 196) = 1.03, p = 0.379
STAI State (initial) – mean (SD)	38.74 (10.86)	39.18 (10.45)	36.72 (9.75)	39.74 (11.78)	F(3, 196) = 0.75, p = 0.523
STAI Trait – mean (SD)	46.84 (9.62)	46.52 (9.96)	47.41 (11.68)	50.28 (13.14)	F(3, 194) = 1.18, p = 0.320
Mini SPIN – mean (SD)	6.06 (2.93)	5.44 (2.76)	6.12 (3.24)	6.00 (3.67)	F(3, 196) = 0.49, p = 0.689

Notes: LOC = Locus of Control, IE4 = Internal-External 4 questionnaire, STAI = State-Trait Anxiety Inventory, SPIN = Social Phobia Inventory. *Post-hoc comparisons (Tukey multiple pairwise-comparisons test) revealed significant differences in age between the Low Control +

Low Social Feedback condition with both the High Control + Low Social Feedback condition (p = 0.006) and High Control + High Social Feedback condition (p = 0.022).

Sensitivity Analyses Including Age – Study 1

To investigate whether age correlated with task performance, a Pearson's correlation between age and the number of wins during the WS task was conducted for high and low control variations separately. There was no correlation between age and performance in the low control (multi-press, $r(98) = 0.069$, $p = 0.496$), nor the high control (single-press, $r(98) = -0.011$, $p = 0.912$). Age also did not correlate with the Locus of Control measures at pre-task (IE4 Internal r(198) = -0.043, $p = 0.543$; IE4 External $r(198) = 0.010$, $p = 0.894$; LOC $r(198) = -0.132$, $p = 0.063$) or at post-task (IE4 Internal $r(198) = -0.105$, $p = 0.141$; IE4 External r(198) = 0.045, $p = 0.529$; LOC $r(198) = -0.134$, $p = 0.059$). Age was also added as a co-variate to the linear mixed effects models predicting subjective control, difficulty, and stress (Table S3). This showed that age did not significantly predict control, difficulty or stress, nor did it change any of the inferences made from the original models that did not include age.

Table S3

Study 1. Results from the linear mixed effects models now including age as a covariate for Study 1 analyses, predicting local control beliefs, perceived difficulty, and stress.

	Local Control Beliefs			**Perceived Difficulty**			**Subjective Stress**		
Predictors	*B*	*β*	*p*	*B*	*β*	*p*	*B*	*β*	*p*
(Intercept)	66.58	0.37	**<0.001**	58.72	-0.13	**<0.001**	19.09	-0.12	0.067
Control [Low]	-12.91	-0.49	**<0.001**	1.36	0.05	0.695	0.63	0.02	0.889
Social Feedback [Low]	-7.47	-0.28	**0.041**	-2.86	-0.11	0.405	-0.96	-0.04	0.829
Control [Low] × Social Feedback [Low]	1.74	0.07	0.738	16.10	0.62	**0.001**	13.56	0.51	**0.033**
Age	0.13	0.02	0.637	0.14	0.03	0.600	0.15	0.03	0.672
Perceived Difficulty	-0.20	-0.19	**<0.001**						
Local Control Beliefs				-0.20	-0.21	**<0.001**			
Baseline Stress							0.40	0.40	**<0.001**
Random Effects									
σ^2	244.04			243.46			103.72		
τ_{00}	309.72 $_{ppt}$			269.34 $_{ppt}$			466.63 $_{ppt}$		
	1.05 $_{timepoint}$			3.01 $_{timepoint}$			0.42 $_{timepoint}$		
ICC	0.56			0.53			0.82		

N	200 ppt 10 timepoint	200 ppt 10 timepoint	200 ppt 4 timepoint
Observations	2000	2000	800
Marginal R^2 / Conditional R^2	0.140 / 0.622	0.156 / 0.601	0.219 / 0.858

Table S4

Linear mixed effects model predicting local control beliefs in Study 1.

	Local Control Beliefs							
Predictors	*β*	*(95% CI)*	*SE β*	*B*	*t*	*p*	*part R^2*	*(95% CI)*
(Intercept)	0.36	0.17 – 0.56	0.10	70.22	24.84	**<0.001**		
Control [Low]	-0.48	-0.75 – -0.21	0.14	-12.72	-3.49	**0.001**	0.074	0.025 – 0.124
Social Feedback [Low]	-0.28	-0.55 – -0.01	0.14	-7.52	-2.06	**0.039**	0.023	0.000 – 0.073
Perceived Difficulty	-0.19	-0.24 – -0.15	0.02	-0.20	-8.99	**<0.001**	0.037	0.002 – 0.088
Control [Low] × Social Feedback [Low]	0.07	-0.31 – 0.46	0.20	1.96	0.38	0.704	0.000	0.000 – 0.067
Random Effects								
σ^2	244.04							
$\tau_{00\ ppt}$	308.36							
$\tau_{00\ timepoint}$	1.05							
ICC	0.56							
N_{ppt}	200							
$N_{timepoint}$	10							
Observations	2000							
Marginal R^2 / Conditional R^2	0.140 / 0.621							

Perceived Task Difficulty – Study 1

To test how the inference of control influenced perceived task difficulty, a linear mixed effects model predicting difficulty responses from control and social feedback conditions and their interaction. Given the high correlation between difficulty and subjective control (r=-0.67, $p<.001$), we included subjective control as a covariate. Given that control and difficulty sliders were asked every-other-block, the timepoints were collapsed across every two blocks. Participant and timepoint were included as random effects. Lower subjective control (β=-0.21, $p<.001$) was associated with higher difficulty ratings. There was a significant interaction of social feedback and control (β=0.63, $p=.001$) such that receiving low social feedback increased perceived difficulty only in low control (β= 13.42, SE=3.43, $t(197)=3.916$, $p_{\text{adj.}}<.001$) but not high control conditions (β= -2.92, SE=3.42, $t(196)=0.851$, $p_{\text{adj.}}=.396$). There were no main effects of social feedback (β=-0.11, $p=.395$) or control condition (β=0.06, $p=.651$, Figure S1, Table S5).

Subjective Stress – Study 1

To test how the social feedback and control conditions related to feelings of stress, another linear mixed effects model was run predicting stress slider responses (four sliders during the task) from control and social feedback conditions and their interaction, with participants' initial stress slider response (pre-task) as a covariate. Participant and timepoint were included as random effects. As expected, higher initial stress ratings predicted higher stress during the WS task (β=0.40, $p<.001$). There was a significant interaction of social feedback and control (β=0.52, $p=.028$) such that receiving low social feedback increased subjective stress only in low control (β= 12.79, SE=4.44, $t(195)=2.88$, $p_{adj.}=.009$) but not high control conditions (β= -1.03, SE=4.44, $t(195)=-0.233$, $p_{adj.}=.816$). There were no main effects of social feedback (β=-0.04, $p=.816$) nor of control condition (β=0.03, $p=.852$) (Figure S2, Table S5).

Figure S1

Mean and standard error bars of perceived difficulty across Study 1.

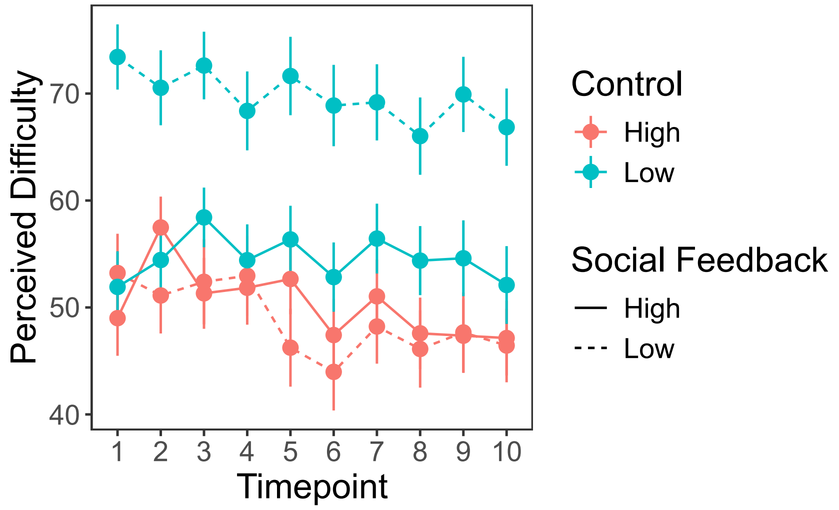

Figure S2

Mean and standard error bars of subjective stress across Study 1.

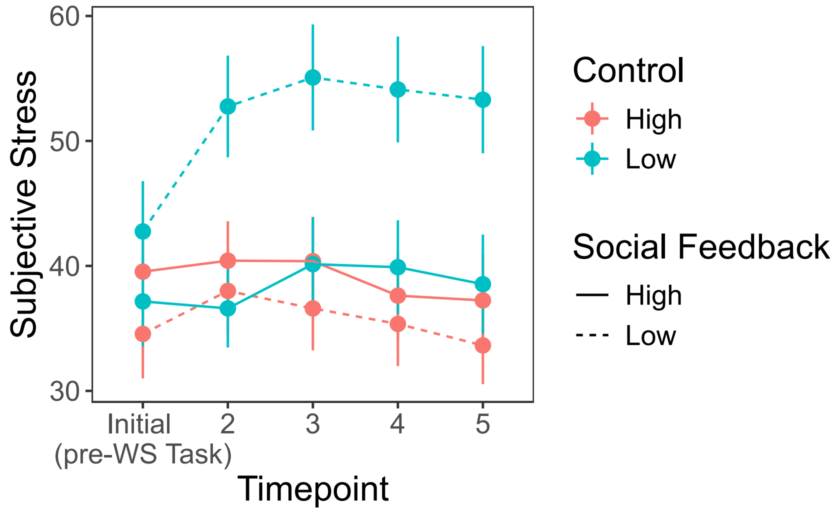

Table S5

Study 1. Linear mixed effects model of perceived difficulty and subjective stress during the WS task.

	Perceived Difficulty						Subjective Stress					
Predictors	*β*	*(95% CI)*	*SE β*	*B*	*t*	*p*	*β*	*(95% CI)*	*SE β*	*B*	*t*	*p*
(Intercept)	-0.13	-0.32 – 0.06	0.10	62.51	22.28	**<0.001**	-0.13	-0.36 – 0.11	0.12	23.17	5.90	**<0.001**
Control [Low]	0.06	-0.20 – 0.32	0.13	1.55	0.45	0.651	0.03	-0.29 – 0.36	0.17	0.83	0.19	0.852
Social Feedback [Low]	-0.11	-0.37 – 0.15	0.13	-2.92	-0.85	0.395	-0.04	-0.36 – 0.29	0.17	-1.03	-0.23	0.816
Control [Low] × Social Feedback [Low]	0.63	0.27 – 1.00	0.19	16.33	3.38	**0.001**	0.52	0.05 – 0.98	0.24	13.82	2.20	**0.028**
Local Control Beliefs	-0.21	-0.25 – -0.16	0.02	-0.20	-9.32	**<0.001**						
Baseline Stress							0.40	0.28 – 0.51	0.06	0.40	6.71	**<0.001**
Random Effects												
σ^2	243.47						103.72					
τ_{00}	268.22 $_{ppt}$						464.55 $_{ppt}$					
	3.02 $_{timepoint}$						0.42 $_{timepoint}$					
ICC	0.53						0.82					
N	200 $_{ppt}$						200 $_{ppt}$					
	10 $_{timepoint}$						4 $_{timepoint}$					
Observations	2000						800					
Marginal R^2 / Conditional R^2	0.156 / 0.601						0.219 / 0.858					

Study 1 – Rotter's Locus of Control and IE4-Internal pre- to post-task

We investigated whether the control and social feedback conditions changed locus of control scores from pre- to post-task in Study 1 using a mixed ANOVA. Statistics for IE4-External are reported in the main text.

Rotter's Locus of Control

There was a main effect of control ($F(1,195)=6.156$, $p=.014$, $\eta^2=0.031$), such that those in the high control condition had higher LOC scores (more external) at both time points (thus reflecting pre-existing differences before the task). There were no other main effects or interactions with social feedback or time (all *p*s>.05) on LOC scores, suggesting that the WS task manipulation did not change LOC scores for this measure.

IE4 Internal

There was a main effect of timepoint on IE4-Internal scores ($F(1,196)=16.08$, $p<.001$, $\eta^2=0.076$), reflecting that all groups had lower internal scores after the WS task (Figure 3). There were no other main effects of control, social feedback, or interactions with time. This shows that participants' internal sense of control on the IE4 scale decreased from the task, but this was not different depending on the socially informed control inferences probed by the experiment.

Figure S3

Study 1 mean and standard error bars of IE4 internal and external scores pre- and post-task.

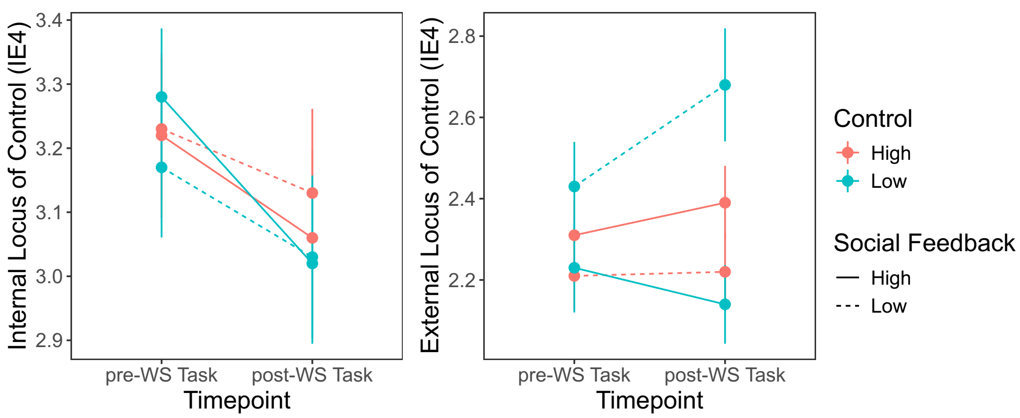

Table S6

Study 2 descriptive statistics across the 4 conditions. Group differences were assessed using a one-way ANOVA for continuous variables or a Chi-squared test for categorical variables.

	Control	High Control		Low Control		Group Differences
	Social Feedback	High	Low	High	Low	
N		110	113	105	108	X(3, N=436) = 0.312, p = 0.958
N grid task exclusions – n (%)		18 (16.4)	21 (18.5)	13 (12.4)	16 (14.8)	X(3, N=436) = 1.690, p = 0.639
Age – mean (SD)		27.7 (4.35)	28.1 (4.45)	27.6 (4.41)	27.8 (4.92)	F(3, 432) = 0.319, p = 0.812
Female – n (%)		46 (41.82)	52 (46.02)	49 (46.67)	59 (54.63)	X(3, N=436) = 3.745, p = 0.290
Nationality UK – n (%)		82 (74.45)	84 (74.34)	85 (80.95)	84 (77.78)	X(3, N=436) = 1.774, p = 0.621
First language English – n (%)		101 (91.82)	98 (86.73)	96 (91.43)	89 (82.41)	X(3, N=436) = 6.09, p = 0.107
Ethnicity – n (%)	Asian	13 (11.82)	12 (10.62)	9 (8.57)	10 (9.26)	X(12, N=436) = 5.33, p = 0.946
	Black	17 (15.45)	11 (9.73)	16 (15.24)	17 (15.74)	
	Mixed	8 (7.27)	8 (7.08)	4 (3.81)	7 (6.48)	
	Other	2 (1.82)	1 (0.88)	2 (1.90)	1 (0.93)	
	White	70 (63.64)	81 (71.68)	74 (70.48)	73 (67.59)	

Subjective SES – mean (SD)	5.44 (1.69)	5.42 (1.49)	5.47 (1.58)	5.25 (1.61)	$F(3, 380) = 0.381, p = 0.766$
Education Level – mean (SD)	3.91 (0.80)	3.80 (0.92)	3.81 (0.92)	3.81 (0.93)	$F(3, 432) = 0.386, p = 0.763$
IE4 Internal (initial) – mean (SD)	3.04 (0.85)	3.04 (0.76)	3.07 (0.86)	3.08 (0.83)	$F(3, 432) = 0.089, p = 0.966$
IE4 External (initial) – mean (SD)	2.37 (0.78)	2.34 (0.75)	2.27 (0.74)	2.39 (0.71)	$F(3, 432) = 0.544, p = 0.652$
PHQ – mean (SD)	6.51 (5.61)	6.36 (5.43)	7.00 (5.19)	7.10 (5.04)	$F(3, 432) = 0.507, p = 0.678$
GAD – mean (SD)	5.41 (4.79)	5.04 (4.99)	5.81 (4.98)	5.34 (4.16)	$F(3, 432) = 0.489, p = 0.690$
Mini SPIN – mean (SD)	4.12 (3.36)	4.57 (3.25)	4.68 (3.39)	4.48 (3.13)	$F(3, 432) = 0.591, p = 0.621$

Notes: SES = Socioeconomic Status, IE4 = Internal-External 4 questionnaire, PHQ = Patient Health Questionnaire, GAD = Generalised Anxiety Disorder questionnaire, SPIN = Social Phobia Inventory. Missing data from n=52 (5-19 missing per group) for SES due to a technical error.

WS Task Perceived Difficulty and Subjective Stress – Study 2

We conducted additional exploratory analyses assessing how perceived difficulty changed dependent on the experimental conditions. A two-way ANOVA showed there were no significant differences of perceived difficulty at baseline dependent on control and social feedback group allocations (control: $F(1,432)=0.403$, $p=.526$, social feedback: $F(1,432)=1.875$, $p=.172$, control and social feedback interaction: $F(1,432)=1.206$, $p=.273$). We included subjective control at each timepoint as a covariate, given the high correlation between difficulty and subjective control ($r=-0.749$, $p<.001$) to isolate effects on perceived difficulty. A linear mixed effects model allowing for random effects of participant and timepoint showed main effects of control condition ($\beta=0.25$, $p<.001$) and subjective control ($\beta=-0.63$, $p<.001$) but not of social feedback ($\beta=0.09$, $p=.159$) nor an interaction between control and social feedback ($\beta=-0.02$, $p=.859$, Table S7, Figure S4). This is unlike Study 1, which found a significant interaction such that the low control low social feedback group perceived the task as more difficult, even when accounting for subjective control ratings.

Similarly, we wanted to explore the effects of stress across the course of the experiment. There were there no differences in stress after the baseline block dependent on control and social feedback group allocations (control: $F(1,432)=0.135$, $p=.713$, social feedback: $F(1,432)=0.515$, $p=.473$, control and social feedback interaction: $F(1,432)=0.018$, $p=.892$), but we nevertheless still included baseline stress as a co-variate, given it would likely impact later stress in the task. A linear mixed effects model allowing for random effects of participant and timepoint showed main effects of control condition ($\beta=0.25$, $p<.001$) and baseline stress ($\beta=0.74$, $p<.001$) and of social feedback ($\beta=0.29$, $p<.001$, Table S7, Figure S5), such that low control and low social feedback both predicted higher levels of stress. There was no interaction between control and social feedback ($\beta=-0.08$, $p=.448$).

These results show that the socially informed inferences of control impacted block-level estimates of subjective stress. The low control and low social feedback condition (i.e. *"I am barely in control")* had higher stress ratings than the low control and high social feedback group (i.e. *"this task is uncontrollable"*), and the high control and high social feedback group (i.e. *"I am highly in control"*) had lower stress than the high control low social feedback groups (i.e. *"this task is controllable"*). These differences may be explained by the transactional view of stress and coping by Lazarus and Folkman (1984). This proposes that stress occurs when the perceived demands of a situation exceed the perceived resources of the system to meet those demands, especially when the system's wellbeing is judged or perceived as being at stake. The system, here, is the individual performing the WS task, and it is possible the monetary bonus ensures participants feel their performance is at stake. Comparative performance feedback likely informs participants about their own resources to meet those demands, since in the low social feedback conditions they may be led to believe they are not adequately meeting demands compared to others due to worse performance in the same task.

Figure S4

Mean and standard error bars of perceived difficulty across the experiment in Study 2.

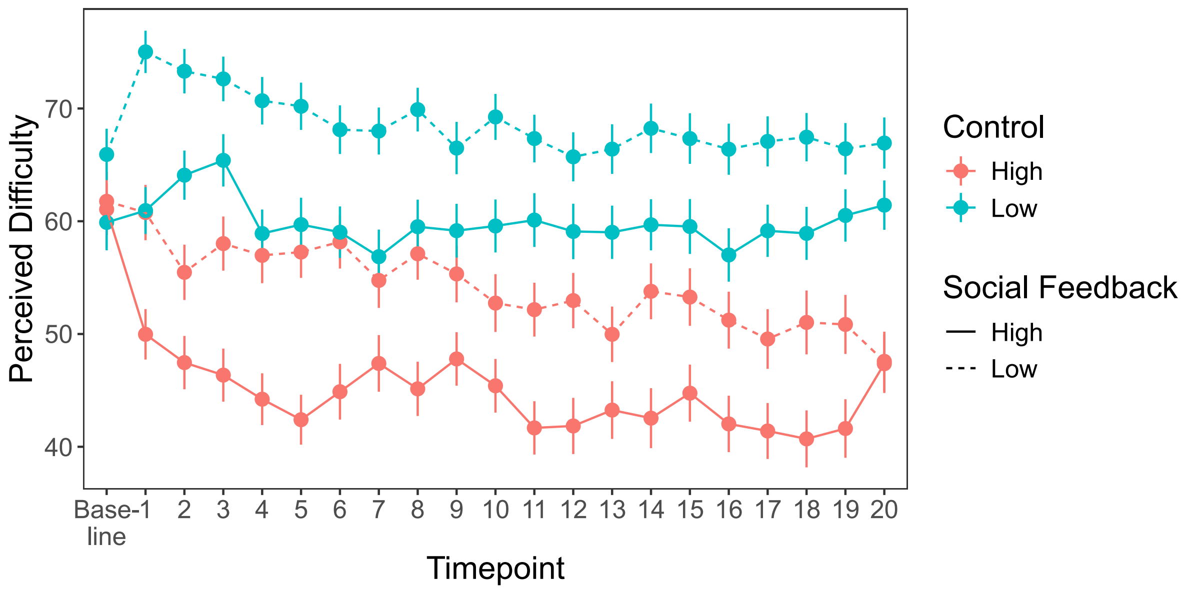

Figure S5

Mean and standard error bars of subjective stress across the experiment in Study 2.

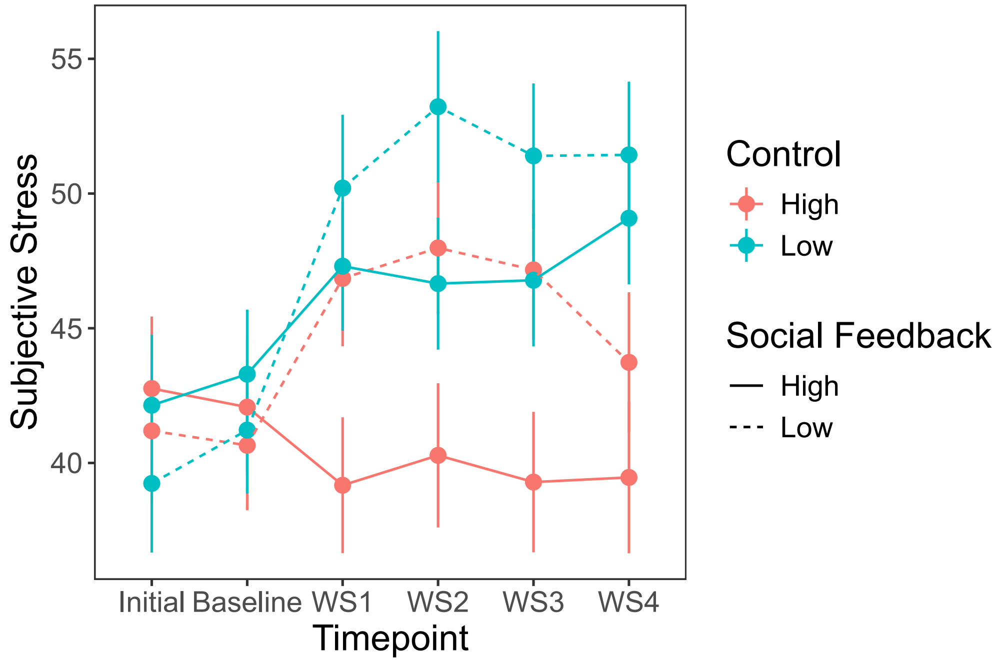

Table S7

Study 2. Linear mixed effects model of perceived difficulty and subjective stress during the WS task.

	Perceived Difficulty						Subjective Stress					
Predictors	*β*	*(95% CI)*	*SE β*	*B*	*t*	*p*	*β*	*(95% CI)*	*SE β*	*B*	*t*	*p*
(Intercept)	-0.16	-0.26 – -0.07	0.05	80.95	60.46	**<0.001**	-0.25	-0.36 – -0.15	0.05	5.86	3.04	**0.002**
Control [Low]	0.25	0.12 – 0.38	0.07	6.45	3.69	**<0.001**	0.25	0.10 – 0.40	0.08	6.93	3.28	**0.001**
Social Feedback [Low]	0.09	-0.04 – 0.22	0.07	2.42	1.41	0.159	0.29	0.14 – 0.44	0.08	8.02	3.87	**<0.001**
Control [Low] × Social Feedback [Low]	-0.02	-0.20 – 0.17	0.09	-0.44	-0.18	0.859	-0.08	-0.29 – 0.13	0.11	-2.25	-0.76	0.448
Subjective Control	-0.63	-0.65 – -0.62	0.01	-0.61	-81.09	**<0.001**						
Baseline Stress							0.74	0.68 – 0.79	0.03	0.80	27.20	**<0.001**
Random Effects												
σ^2	140.76						117.95					
τ_{00}	156.53 $_{ppt}$						209.62 $_{ppt}$					
	2.05 $_{timepoint}$						0.03 $_{timepoint}$					
ICC	0.53						0.64					
N	436 $_{ppt}$						436 $_{ppt}$					
	20 $_{timepoint}$						4 $_{timepoint}$					
Observations	8720						1744					
Marginal R^2 / Conditional R^2	0.518 / 0.773						0.565 / 0.843					

Robustness Checks

To assess the external validity of our task measures, we investigated the correlations of questionnaire measures (measuring symptoms of mental ill-health and locus of control) with the baseline attribution measures, as well as mean local control beliefs (subjective control) and stress ratings during the experiment. Replicating prior work (Fielder et al., 2025), we found that after accounting for experimental control and social feedback conditions, lower levels of self-reported control during the WS task (mean local control beliefs), on average, were associated with higher symptoms of depression (Study 2 PHQ β=-0.17, $p_{adj.}$<.001), anxiety (Study 1 STAI-T: β=-0.18, $p_{adj.}$=.012, Study 1 STAI-S: β=-0.27, $p_{adj.}$<.001, Study 2 GAD β=-0.17, $p_{adj.}$<.001), social phobia (Study 2: β=-0.14, $p_{adj.}$=.002, though not in Study 1: β=-0.06, $p_{adj.}$=.432), higher external locus of control (Study 1 Rotter's LOC: β=-0.20, $p_{adj.}$=.008, Study 1 IE4 External: β=-0.18, $p_{adj.}$=.010, Study 2 IE4 External: β=-0.11, $p_{adj.}$=.010), and lower internal locus of control (Study 2 IE4 Internal: β=0.15, $p_{adj.}$=.001, though not in Study 1: β=0.05, $p_{adj.}$=.432) (Tables S8 & S10). We also found that after accounting for experimental control and social feedback condition, higher levels of self-reported stress during the WS task, on average, were associated with higher symptoms of depression (Study 2 PHQ: β=0.38, $p_{adj.}$<.001), anxiety (Study 1 STAI-T: β=0.29, $p_{adj.}$<.001, Study 1 STAI-S: β=0.43, $p_{adj.}$<.001, Study 2 GAD: β=0.43, $p_{adj.}$<.001), social phobia (Study 1: β=0.16, $p_{adj.}$=.025, Study 2: β=0.33, $p_{adj.}$<.001), higher external locus of control (Study 1 Rotter's LOC: β=0.23, $p_{adj.}$=.001, Study 1 IE4 External: β=0.29, $p_{adj.}$<.001, Study 2 IE4 External: β=0.18, $p_{adj.}$<.001), but not associated with internal locus of control (Study 1 IE4 Internal: β=-0.08, $p_{adj.}$=.273, Study 2 IE4 Internal: β=-0.05, $p_{adj.}$=.369) (Tables S9 & S11). Thus, control beliefs and stress during the WS task were robustly associated with mental health.

We also assessed the external validity of our control attribution measure (rating of their ability to control the wheel and the reason why) by assessing individual differences at baseline. Specifically, we were interested in how self-reported attribution related to our locus of control measures, as we would expect a greater self-attribution to correlate with higher initial internal locus of control (or greater task-attribution to correlate with higher initial external locus of control). A multivariate linear regression showed that internal locus of control was significantly associated with the attribution sliders assessed together as the two dependent variables (Pillai's Trace = 0.028, $F(2, 433) = 6.128$, $p = .002$). Univariate follow up tests indicated that internal locus of control was associated with both the rating of participants' ability to control the wheel ($F(1, 434) = 10.87$, $p = .001$) and the specific attribution why ($F(2, 434) = 4.24$, $p = .040$), with higher internal locus of control predicting greater ability and greater self-attribution. We found no associations between external locus of control and the attribution measure (Pillai's Trace = 0.001, $F(2, 433) = 0.124$, $p = .884$).

To check the validity of our grid task, we assessed whether the grid task showed expected effects of learning, and whether our pre-registered criterion of being a grid learner (successfully escaping at least one third of trials) was associated with expected differences in task behaviour in terms of the time taken to 'escape' the scream over the course of the task (Figure S6). A linear mixed effects model predicting the time to escape (allowing for random effect of participant) revealed a significant interaction between trial number and grid learner status ($\beta = -0.18$, $p < .001$), such that the time to escape significantly decreased across the experiment for grid learners ($\beta = -0.43$, $p < .001$), but not for non-learners ($\beta = -0.01$, $p = 0.517$), indicative of learning.

We additionally categorised participants' free text responses of what action they performed to terminate the scream into three categories: 1) the correct solution (e.g. mentioning getting the counter to the other side, opposite side), 2) answers than indicated moving on the grid or performing an action but not the exact correct solution (e.g. searching for the scream, going to the corners, going to edges but the *opposite* edge not specified), and 3) indications of no solution or attempt to solve the grid (e.g. no response, waiting, just focussing on the pitch discrimination task). Two coders independently coded the free text responses (Cohen's weighted kappa = 0.96) and disagreements were discussed and agreed upon. There was a significant association between grid learner distinction as defined from task performance (winning at least one third of trials) and the free text responses ($X(2, N=368) = 177.28$, $p = <.001$). Of grid learners, 89.3% were coded into category 1 or 2 indicating that they knew the correct response or were performing actions on the grid, while 79.4% of non-learners were coded into category 3 indicating they did not know how to solve the task.

Table S8

Associations between mean control during the WS task (dependent variable) and questionnaire items of mental health and locus of control in Study 1.

	Mean Local Control Beliefs (during WS task)											
	STAI Trait		STAI State		Mini SPIN		Rotter's LOC		IE4 External		IE4 Internal	
Predictors	*β*	$p_{adj.}$	*β*	$p_{adj.}$	*β*	$p_{adj.}$	*β*	$p_{adj.}$	*β*	$p_{adj.}$	*β*	$p_{adj.}$
(Intercept)	0.49	**<.001**	0.49	**<.001**	0.51	**<.001**	0.55	**<.001**	0.49	**<.001**	0.50	**<.001**
Social Feedback [Low]	-0.35	**.009**	-0.32	**.013**	-0.37	**.009**	-0.38	**.009**	-0.35	**.009**	-0.36	**.009**
Control [Low]	-0.63	**<.001**	-0.67	**<.001**	-0.65	**<.001**	-0.71	**<.001**	-0.63	**<.001**	-0.65	**<.001**
STAI Trait	-0.18	**.012**										
STAI State			-0.27	**<.001**								
Mini SPIN					-0.06	.432						
Rotter's LOC							-0.20	**.008**				
IE4 External									-0.18	**.010**		
IE4 Internal											0.05	.432
Observations	198		200		200		199		200		200	
R^2 / R^2 adjusted	0.176 / 0.163		0.211 / 0.199		0.143 / 0.129		0.177 / 0.165		0.173 / 0.161		0.142 / 0.129	

Notes: p_{adj} = *p*-value adjusted for multiple comparisons due to running 6 separate models.

Table S9

Associations between mean stress during the WS task and questionnaire items of mental health and locus of control in Study 1.

	Mean Stress (during WS task)											
	STAI Trait		STAI State		Mini SPIN		Rotter's LOC		IE4 External		IE4 Internal	
Predictors	*β*	$p_{adj.}$	*β*	$p_{adj.}$	*β*	$p_{adj.}$	*β*	$p_{adj.}$	*β*	$p_{adj.}$	*β*	$p_{adj.}$
(Intercept)	-0.26	.562	-0.27	.562	-0.30	**<.001**	-0.34	.230	-0.27	.158	-0.29	**<.001**
Social Feedback [Low]	0.21	.153	0.17	.183	0.26	.153	0.26	.153	0.22	.153	0.23	.153
Control [Low]	0.32	**.020**	0.38	**.008**	0.34	**.020**	0.42	**.008**	0.32	**.020**	0.35	**.020**
STAI Trait	0.29	**<.001**										
STAI State			0.43	**<.001**								
Mini SPIN					0.16	**.025**						
Rotter's LOC							0.23	**.001**				
IE4 External									0.29	**<.001**		
IE4 Internal											-0.08	.273
Observations	198		200		200		199		200		200	
R^2 / R^2 adjusted	0.129 / 0.116		0.227 / 0.215		0.071 / 0.057		0.096 / 0.082		0.128 / 0.115		0.051 / 0.036	

Notes: p_{adj} = *p*-value adjusted for multiple comparisons due to running 6 separate models.

Table S10

Associations between mean control during the WS task and questionnaire items of mental health and locus of control in Study 2.

	Mean Local Control Beliefs (during WS task)									
	PHQ		**GAD**		**Mini SPIN**		**IE4 External**		**IE4 Internal**	
Predictors	*β*	$p_{adj.}$	*β*	$p_{adj.}$	*β*	$p_{adj.}$	*β*	$p_{adj.}$	*β*	$p_{adj.}$
(Intercept)	0.57	**<.001**	0.58	**<.001**	0.57	**<.001**	0.57	**<.001**	0.58	**<.001**
Social Feedback [Low]	-0.52	**<.001**	-0.53	**<.001**	-0.51	**<.001**	-0.51	**<.001**	-0.52	**<.001**
Control [Low]	-0.62	**<.001**	-0.63	**<.001**	-0.63	**<.001**	-0.65	**<.001**	-0.65	**<.001**
PHQ	-0.17	**<.001**								
GAD			-0.17	**<.001**						
Mini SPIN					-0.14	**.002**				
IE4 External							-0.11	**.010**		
IE4 Internal									0.15	**.001**
Observations	436		436		436		436		436	
R^2 / R^2 adjusted	0.200 / 0.194		0.199 / 0.194		0.191 / 0.185		0.184 / 0.178		0.193 / 0.187	

Notes: p_{adj} = *p*-value adjusted for multiple comparisons due to running 5 separate models.

Table S11

Associations between mean stress during the WS task and questionnaire items of mental health and locus of control in Study 2.

	Mean Stress (during WS task)									
	PHQ		**GAD**		**Mini SPIN**		**IE4 External**		**IE4 Internal**	
Predictors	β	$p_{adj.}$	β	$p_{adj.}$	β	$p_{adj.}$	β	$p_{adj.}$	β	$p_{adj.}$
(Intercept)	-0.17	**<.001**	-0.19	**<.001**	-0.17	**<.001**	-0.19	**<.001**	-0.19	**<.001**
Social Feedback [Low]	0.17	.100	0.20	.094	0.15	.100	0.15	.100	0.17	.100
Control [Low]	0.17	**.050**	0.19	**.039**	0.19	**.039**	0.22	**.039**	0.22	**.039**
PHQ	0.38	**<.001**								
GAD			0.43	**<.001**						
Mini SPIN					0.33	**<.001**				
IE4 External							0.18	**<.001**		
IE4 Internal									-0.05	.289
Observations	436		436		436		436		436	
R^2 / R^2 adjusted	0.160 / 0.154		0.203 / 0.197		0.126 / 0.120		0.050 / 0.043		0.021 / 0.014	

Notes: p_{adj} = *p*-value adjusted for multiple comparisons due to running 5 separate models

Figure S6

Time to escape over the course of the grid task, split by grid learners and non-learners.