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Sense of agency in social hierarchies

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Abstract

Distributing complex actions across agents is commonplace in human society. The objective efficiency of joint actions comes with critical challenges for the sense of agency of individual agents, complicating an accurate formation of these agents' perceived control over actions and action outcomes. Here we report a new experimental paradigm to investigate sense of agency for supervisors and subordinates in hierarchical settings. Results indicate profound differences in the sense of agency between both roles, while also indicating additional contributions of such situational factors as degrees of freedom, action decision vs. action execution, outcome valence, and veto options. We further observed a tight coupling of sense of agency and sense of responsibility, with only weak links to affective responses to the action outcome.

Keywords: sense of agency; joint agency; hierarchies; responsibility; valence of outcome

Public Significance Statement

Sense of agency refers to the firm belief that we are in control of our actions and can, through these actions, effect changes in our environment. We often do not act alone, however, and common findings from single-agent scenarios cannot be expected to transfer easily to multi-agent interactions. Indeed, real world crises such as the financial crisis of 2007 are often facilitated by situations fostering poor sense of agency formation in all involved agents on different hierarchical levels. Understanding how sense of agency arises in joint actions therefore matters for understanding such events. The present series of experiments thus pioneers a new experimental approach to unravel when supervisors and subordinates feel agency over the outcomes of joint actions and when they do not.

Introduction

Whenever we act, we do so with the underlying belief that we are in control of our actions and that we can effect changes in the environment through these actions (Frith, 2014; Haggard, 2017; Moore, 2016; Wen & Imamizu, 2022). This sense of agency is a crucial part of goal-directed behavior, which helps to evaluate the effectiveness of past actions and motivates future actions (Eitam et al., 2013; Gozli, 2019; Gozli & Dolcini, 2018; Karsh & Eitam, 2015; Karsh et al., 2016; Schwarz et al., 2022). As such, it is associated with a variety of downstream consequences, from a sense of responsibility for our actions, to feelings of happiness or regret with regards to the action outcome (Frith, 2014). And even further, sense of agency is directly linked to our understanding of justice and law, to philosophical ideas of the self, while atypical sense of agency is associated with a variety of psychological disorders (Blakemore et al., 2000; Frith, 2014; Gallagher, 2000; Giuliani et al., 2021; Miyawaki et al., 2022; Möller et al., 2021; Seghezzi et al., 2021; Szalai, 2019; Weller et al., 2020).

Because of its widespread relevance to a number of fields, the formation of sense of agency has gained considerable attention in the past years, mostly focusing on simple actions by a single agent. This work has elucidated that sense of agency derives from both sensorimotor signals as well as post-hoc integration of additional cues (Moore et al., 2009; Moore & Fletcher, 2012; Synofzik et al., 2008). Such cues include, for example, the questions of priority (“Was there a conscious action intention before the action?”), consistency (“Was this action intention consistent with the action?”), and exclusivity (“Was my action the only possible cause for the change in the environment that I just witnessed?”) (Wegner, 2003). Depending on the situation, these diverse signals will be weighted differently on different levels of representation and result in varying degrees of sense of agency (Chambon et al., 2014; Lafleur et al., 2020; Moore & Fletcher, 2012; Pacherie, 2008; Schwarz et al., 2018a). However, matters are considerably more complex when acting in tandem with one or more agents, hence joint action. Already including one additional person into the equation poses critical challenges to the sense of agency by violating the principle of exclusivity, and by rendering action-effect sequences less predictable (Hayashida et al., 2021; Knoblich et al., 2011; Loehr, 2022; Pacherie, 2014; Schuch & Tipper, 2007; Sebanz et al., 2006a, b; Silver et al., 2021; Tsai et al., 2006; van der Weiden et al., 2022; Zapparoli et al., 2022).

Despite the challenges of joint actions, human agents readily form a sense of agency for actions that require more than one person and they can have both a sense of agency pertaining to their own actions (self-agency) as well as a sense of agency pertaining to the joint venture (we-agency or joint agency; Jenkins et al., 2021; Loehr, 2022; Pacherie, 2014; Silver et al., 2021; van der Wel, 2015). Indeed, previous literature differentiates between three forms of sense of agency in this context: independent agency (termed self-agency in this article), shared agency, and united agency (for a review focusing on the topic of self- vs. joint agency, please see Loehr, 2022). Both shared and united agency refer to a sense of agency that applies to more than one person; however, while shared agency relates to a shared agentic experience in the sense that several agents contribute to a single action and/or outcome (termed joint agency in this article), united agency refers to situations in which several agents act as one and involves a merging of self- and joint agency, primarily found for larger, cohesive group activities such as singing in choirs (Loehr, 2022; Pacherie, 2012). Moreover, individuals can also attribute sense of agency to their co-agents instead of themselves (partner-agency or other-agency). Previous

evidence suggests that joint agency is not simply a summation of self-agency and other-agency, but that it is a unique experience that is dependent on contextual factors, such as the agents' specific task contributions or maybe even task difficulty (Konstrubiec et al., 2018). Indeed, self- and joint agency seem to be affected by different aspects of multi-agent scenarios: whereas motor aspects of the action such as movement fluidity seem to have a stronger influence on self-agency, strategic decision making or social behavioral strategies have been shown to especially affect joint agency (LeBars et al., 2020, 2022).

But how does sense of agency come about in these settings, and how is it influenced by characteristics of the social interaction? Attempting to answer this question by transferring findings from single-agent scenarios to joint actions is not particularly promising. Factors such as group size or group equality have no counterpart in single-agent scenarios. These factors are particularly relevant for understanding subjective agency during joint actions, however, as they might affect real-life outcomes. Global events such as the financial crisis of 2007 might be facilitated because strict hierarchies separate the level of decision making from action execution possibly leading to an altered sense of agency in agents across hierarchies (Merle, 2018; Williams, 2010). Whereas several studies have focused on sense of agency in equal pairs, only limited evidence has been gathered for sense of agency in such hierarchical settings in which action decision and action execution may be unilateral contributions by different agents to a combined action process (see, e.g., Loehr, 2022; Zapparoli et al., 2022). However, studies that have assessed symmetrical versus asymmetrical dyads imply that it is possible to develop sense of agency even for actions that were not executed by oneself, dependent on which role one holds, a phenomenon that has been coined *vicarious agency* (Bolt et al., 2016; Reddish et al., 2020; Wegner et al., 2004). That is, vicarious agency refers to an extended self-agency, in which an agent feels agentic for the actions of others (in contrast to the conceptualization of joint agency in which participants perceive a collective sense of agency that incorporates more than one agent)¹. Most of the studies including a somewhat asymmetrical relationship between agents implemented a relatively soft understanding of social roles with one agent acting as a leader, and the respectively other agents acting as a follower (e.g., Bolt et al., 2016). These more fluctuant leader(decider)-follower relationships substantiate that actual control plays a profound role for the participants' sense of agency (Le Bars et al., 2020; 2022; van der Wel, 2015). Moreover, they also showcase the importance of social factors that affect both self- and joint agency such as perceived fairness or cooperative vs. competitive contexts. However, as roles fluctuated throughout the experiments and sometimes even emerged from the agents' actions themselves, we do not know yet how sustained, clear roles with explicit orders affect sense of agency.

Yet, we often experience situations in which we either give or are given direct action-related orders with a clearly vocalized and sustained hierarchical structure between both involved agents. Prominent studies with such an experimental setup have often focused on

¹ Please note that although the conceptualizations of self-, joint, and vicarious agency differ, they are not exclusive. It is well possible for an agent to feel self-agency, joint agency, and vicarious agency at the same time (Reddish et al., 2020).

coercion and morally difficult actions – and have mainly targeted the perspective of the “commandee” instead of also investigating the perspective of the commanding agent (Caspar et al., 2016, 2020; Caspar et al., 2021). However, there have been some exceptions to the latter: studies that have included the perspective of both higher and lower levels of hierarchy (or “commander” and “commandee”) show that sense of responsibility ratings vary between different roles with commanders showing a higher sense of responsibility than commandees (Caspar et al., 2018; Caspar et al. 2022), indicating that the perspective of both roles is worth considering when studying perceived control or perceived responsibility. Yet, in most real-life settings, whether it is the supervisor-subordinate relationship in a company or even teacher-student or parent-child relationships, instructed actions are much more benign than coercive contexts. Nevertheless, they may affect sense of agency formation in subordinates and supervisors alike.

To gain a general understanding how sense of agency forms in hierarchical dyads, we have developed an experimental paradigm that implements stock-exchange simulations in which two participants are asked to invest virtual money into funds to increase their overall profit. One participant is randomly assigned the role of supervisor, the other the role of subordinate. A positive net result at the end of the experiment translates to an additional monetary reward for both participants. We ran a series of three experiments in this design to target the following five main research questions:

(1) How does an agent’s social role affect sense of agency? In this series of experiments, we aimed to target both the supervisors’ and subordinates’ perspective, investigating self-agency (Experiments 1-3) as well as sense of agency attribution in terms of self- vs. joint agency (Experiment 1). Previous evidence suggests that an agent’s contribution to joint actions affects their sense of agency on individual as well as collective levels (i.e., for self- as well as joint agency; LeBars et al., 2020). Indeed, joint agency seems highest for situations with equal contributions compared to more hierarchical settings, supporting the idea that in hierarchical situations, participants might attribute agency more to either themselves or the other agent than to both equally. In the present study, we go a step further and take an even more differentiated perspective on the factor role in that we expected sense of agency to be generally higher in supervisors even in situations in which they do not wield more control than subordinates (Experiment 1), and we expected supervisors to attribute action outcomes more to themselves than the subordinates as a result of supervisors assuming more responsibility and causation.

(2) Do action decision and action execution² affect sense of agency separately? As previous studies suggest that it makes a difference whether actions are freely executed or action decisions are external (Caspar et al., 2016; Schwarz et al., 2019), we hypothesized that both, action decision and action execution, contribute to sense of agency, leading to an intermediate level of sense of agency if they are distributed across supervisor and subordinate (Experiments 2-3).

² What we coin here as action decision is the original distal action decision (i.e., how much money to invest in which stock). Of course, for any voluntary action, more proximal action decisions also occur (i.e., I will press the button now), but these are not the focus of the action decision vs. action execution analysis.

(3) How does sense of agency relate to perceived responsibility and happiness with outcome? Previous studies have sometimes used classical sense of agency measures (perceived causation, perceived control) synonymously with sense of responsibility (e.g., Schwarz et al., 2019). Indeed, studies implementing both, sense of agency and sense of responsibility measures, show a high similarity in both rating patterns (e.g., Reis et al., 2022). However, so far there have been few attempts to experimentally impact both ratings differentially in order to gain a comprehensive understanding of possible similarities and differences between both concepts. Nevertheless, based on previous evidence, we expected perceived causation to be directly linked to sense of responsibility (Experiments 1-3). Moreover, we expected increasing sense of agency to increase happiness with outcome as sense of agency is perceived as rewarding by agents and associated with increased activity in reward-related brain regions (Leotti & Delgado, 2011; Leotti et al., 2010; Lorenz et al., 2015; Experiments 1-3).

(4) How does action outcome affect sense of agency, sense of responsibility, and happiness with outcome? Previous studies show that positive action outcomes are linked to increased explicit judgements³ of sense of agency and sense of responsibility (Gentsch et al., 2015; Reis et al., 2022). This is in line with the assumption that positive effects of own actions are attributed more strongly to oneself (Miller & Ross, 1975). We thus expected positive action outcomes (i.e., successful investments) to go along with higher sense of agency, sense of responsibility, and happiness with outcome than negative or neutral action outcomes independently of whether an agent acts as supervisor or subordinate (Experiments 1-3).

(5a) How does a lack of actual control affect sense of agency and happiness with outcome, and can the power to veto decisions made on higher levels reinstate perceived control? As lack of actual control has been shown to reduce sense of agency (e.g., Schwarz et al., 2022; van der Weiden et al., 2011), we expect similarly that actual control is reflected in sense of agency measures here, as well as in sense of responsibility, and happiness with outcome (Experiments 1-2). Likewise, we expected even a slight reinstatement of power (i.e., control) through veto options to increase sense of agency, sense of responsibility, and happiness with outcome (Experiments 2-3).

(5b) If veto power indeed affects sense of agency, is this effect purely situational or sustained? This question is at this point exploratory so that we do not have strong hypotheses regarding the outcome. However, we believe that our experimental design with sustained veto

³ Indeed, most studies on this question utilize temporal binding as a measure of sense of agency (e.g., Moretto et al., 2011; Takahata et al., 2012; Yoshie & Haggard, 2013) while its validity as an implicit readout of sense of agency is currently controversially discussed (e.g., Hoerl et al., 2020; Klaffehn et al., 2021; Schwarz et al., 2019; Schwarz & Weller, 2022; Siebertz et al., 2022; Tonn et al., 2021). We therefore are reluctant to draw conclusions on sense of agency from studies which are primarily based on temporal binding measures. Please note, however, that explicit ratings also have to be taken with caution: ratings are subjective to biases such as self-efficacy beliefs (Bandura, 1982) or questions of social desirability. Such biases, of course, invite limitations of interpretation (see also *Limitations and Future Directions* paragraph in the General Discussion). Despite these shortcomings, however, we maintain that explicit ratings are currently the most direct and uncontroversial measure to investigate sense of agency.

options (i.e., subordinates have the option to veto the supervisor's decisions throughout most of the experiment) lends itself more towards a sustained effect of veto power (Experiment 3).⁴

⁴ As an exploratory analysis, we also included personality questionnaires in the first experiment, i.e., the Objectification scale (Gruenwald et al., 2008) as well as the NEO-FFI (Costa & McCrae, 1992) for an analysis of individual factors potentially affecting sense of agency, sense of responsibility, and happiness with outcome (but see Schwarz et al., 2022, for a more thorough study of this research question). This analysis is presented in the Supplementary Material.

Experiment 1

Experiment 1: Methods

Participants

We recruited 94 participants in same-sex pairs. For each pair, one participant was randomly assigned the role of supervisor ($N = 47$, mean age = 26.4 years, range 20-57; 34 females, 13 males; 45 right-handed, 2 left-handed) and the other participant the role of subordinate ($N = 47$; mean age = 27.7 years, range 19-62; 34 females, 13 males; 41 right-handed, 6 left-handed). We collected demographics data by asking participants about their sex/gender (please note that German does not differentiate between both concepts) with options being “female” and “male”. We did not include a non-binary option because participants were specifically recruited as either “female” or “male” to form same-sex pairings for the experiment. Participants were asked about their handedness by giving the options “right-handed”, “left-handed”, and “ambidextrous”. Participants gave their age by writing a number into the response box.

This sample size was based on a power calculation assuming an effect size of $d = 0.64$ (based on own previous work; Weller et al., 2017) which ensures a power of $1 - \beta = .80$, increased by 15% to replace possible drop-outs, resulting in a sample size of ≥ 46 participants per group (92 participants in total).

Participants gave informed consent prior to the experiment and received monetary compensation for participation. Two pairs (4 participants) had to be excluded due to incomplete data sets.

Apparatus

Each participant sat in front of a 24 inch flat screen and operated a standard German QWERTZ-keyboard. Participants sat 2 meters apart and an opaque, 2 m high screen between them precluded any visual interaction. Participants were further instructed not to talk to each other verbally; instead, action choices of either participant during each trial were shown to the other participant via their monitor, subjective ratings in contrast remained confidential and were not shown to the other participant.

Monitors and keyboards of each participant were connected to a single PC; ratings were always first shown and given by the supervisor and then by the subordinate to allow the program to differentiate between both participants' inputs.

Procedure

Participants were first instructed as to their randomly assigned role (supervisor vs. subordinate). They were told that they would take part in a stock exchange game and that, in each trial, they could invest up to 1000 VE (virtual Euros) in one of three different funds (consumer goods, sustainability, or technology). They were further instructed that after some trials, they would be asked to rate, for example, their perceived causation of the outcome, and they were asked to respond as honestly as possible. Finally, they were told that if they (and their co-agent) drew a profit at the end of the experiment, this would be rewarded by an additional monetary compensation of up to 5 Euros depending on the size of the profit. A loss of money at the end of the experiment, in contrast, would not result in any consequence.

Each experiment started with a single practice trial to familiarize the participants with the procedure, followed by 84 experimental trials. At the beginning of each trial, the supervisor was asked to decide which participant (supervisor or subordinate) would choose the amount of money that would be invested and which participant would choose the funds in which that money would be invested (see Figure 1). Although supervisors could make that decision for each trial, a counter on the monitor told them how often they were still allowed to make certain choices, resulting in a final 21 trials for each condition by the end of the experiment: (1) money choice: supervisor, stock choice: supervisor; (2) money choice: supervisor, stock choice: subordinate; (3) money choice: subordinate, stock choice: supervisor; (4) money choice: subordinate, stock choice: subordinate. This equal distribution of trials across all conditions resulted in similar degrees of freedom for both roles regarding action choices (money and stock choice) throughout the experiment. Dependent on the condition, either the supervisor or the subordinate was then prompted to choose the amount of money to be invested and the fund in which the money was to be invested by putting in numbers via the keyboard. If the numbers exceeded the allowed range (1000 VEs; stock numbers 1-3) an error message occurred, and they were asked to enter their response again. Both participants then saw on their monitors the amount of money and the fund chosen as well as the stock development of all three funds: For five times, every 800 ms, the funds would either increase, stay the same or decrease with the last change being the one deciding on a win or loss of VEs in this trial. This procedure was intended to make stock development seem dynamic and changeable over time; the time frame of 800 ms was based on feedback by pilot participants. Stock development (positive, neutral, negative) was randomly chosen for each fund in each trial; however, it was balanced across all funds for each condition. We chose to balance stock development to minimize the potential for the development of obvious strategies such as a continuous bias of one stock over the other which might result in less genuine decision-making and more automatic responses. Nevertheless, although the participants were not given any information on stock development, the balancing of stock development throughout the experiment assured that they could learn that the likelihood of future positive developments increased with each past negative development and vice versa. We calculated control analyses to ensure that participants did, in fact, learn to increase the quality of interpretation of the participants' rating patterns.

In 11 trials of each condition, each participant was then asked to rate their sense of agency on five scales; during the rating process the earned or lost money was always displayed on the monitor. Ratings were given with the computer mouse on a slider representing a visual analogue scale with a value range of 0-100 (see Supplementary Table 1 for the original German wording): (1) perceived causation ("How much did you just feel you caused the win or loss to happen?" from "not at all" to "completely"); (2) attributed causation (self/we/other) ("Who caused the win or loss the most?" from "the other" over "we together" to "myself"); (3) perceived responsibility ("How much did you just feel responsible for the win or loss?" from "not at all" to "completely"); (4) attributed responsibility (self/we/other) ("Who is most responsible the win or loss?" from "the other" over "we together" to "myself"); (5) happiness with outcome (HWO) ("How happy are you with the result of the last trial?" from "I am disappointed" over "undecided" to "I am happy").

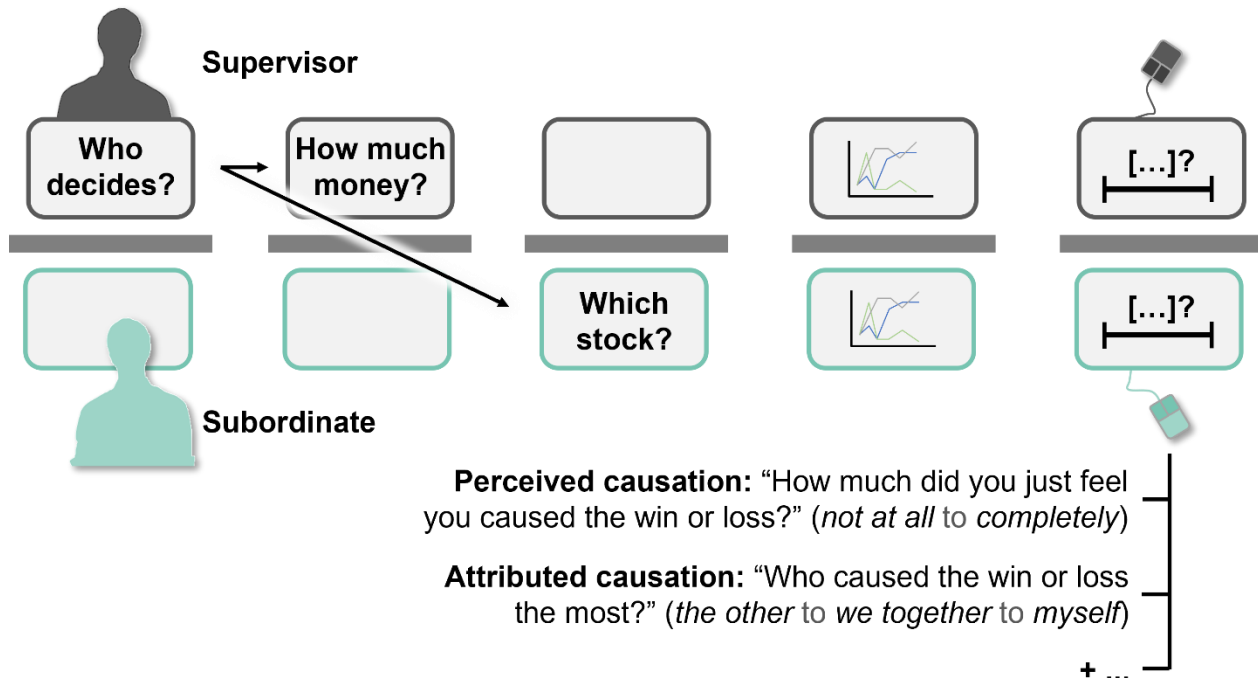


Figure 1. Trial Procedure of Experiment 1. Supervisors determined who would decide the amount of money to spend and who would decide which stock to invest in (here, money choice: supervisor, stock choice: subordinate). A displayed counter ensured that each of the four possible conditions was picked 21 times. Either supervisors (dark grey, upper row) or subordinates (light turquoise, lower row) were then asked to enter the amount of money that would be invested and choose the stock in which the money would be invested, followed by a visualization of the stock development for each fund. In 11 of the 21 trials per condition, both participants were asked to rate their sense of agency on two scales – perceived causation and attributed causation – and to provide additional ratings of perceived responsibility, attributed responsibility, and happiness with outcome.

Data Analysis

Perceived Causation

To probe for the participants' sense of agency, we conducted an analysis of variance (ANOVA) with the between-subjects factor *Role* and the within-subjects factors *Money Choice* and *Stock Choice* for perceived causation. We further calculated attributed causation (self/we/other) for each role and tested the values against "50", the theoretical joint agency value, via one-sample *t*-tests (two-tailed). To assess the impact of outcome on perceived causation, we correlated the participants' average perceived causation ratings with their win or loss over the complete experiment. We further categorized the outcome into three valence levels: negative (losses of more than 50 VE), neutral (wins or losses of equal to or less than 50 VE), and positive (wins of more than 50 VE). We then calculated an ANOVA with the between-subjects factor *Role* and the within-subjects factor *Valence of Outcome*. For all analyses we adopted an alpha-error-level of 5%.

Perceived Responsibility

Analysis of perceived responsibility ratings mirrored the analysis of perceived causation. However, in addition, we calculated a combined perceived responsibility score of each pair by adding the perceived responsibility scores of each participant, and then testing that value against “100” via an one-sample *t*-test (two-tailed), to test whether participants within this experimental context tended to overestimate or underestimate their sense of responsibility. Moreover, we conducted follow-up paired *t*-tests (two-tailed) to test whether different levels of valence of outcome affected perceived responsibility ratings differently.

Happiness With Outcome

For analysis of HWO ratings, we first conducted an ANOVA with the between-subjects factor *Role* and the within-subjects factors *Money Choice* and *Stock Choice*, followed by paired *t*-tests (two-tailed) testing for the impact of *Stock Choice*, separately for each role. HWO ratings were then correlated with the outcome, followed by an ANOVA with the between-subjects factor *Role* and the within-subjects factor *Valence of Outcome*.

Control Analysis: Learning Effects

We looked for potential learning effects by testing the mean total of outcome against zero in one-sample *t*-test. We further categorized trials into four quantiles (quantile 1 = trials 1-21, quantile 2 = trials 22-42, quantile 3 = trials 43-63, quantile 4 = trials 64-84), and calculated an ANOVA with the within-subjects factor quantile to evaluate whether outcome changed across different quantiles.

Transparency and Openness

The data and analysis scripts for Experiment 1 are publicly accessible on the Open Science Framework (osf.io/hjvxp/). Experiment 1 was preregistered; the preregistration is available on the Open Science Framework (osf.io/b9k4m/).

Experiment 1: Results

Supplementary Tables 3-5 summarize the main analyses for perceived causation, perceived responsibility, and happiness with outcome.

Perceived Causation

Although both roles only slightly differed in their degrees of freedom regarding action decisions, supervisors reported higher causation ratings throughout the experiment, $F(1, 88) = 22.67, p < .001, \eta_p^2 = .20$ (see *Figure 2A*; see *Supplementary Table 3* for an overview of results). However, across conditions, participants were very conscious of their actual situational control, with participants reporting the highest causation ratings when they made decisions regarding both money and stock choice, lowest when their co-agent made both decisions, and intermediate when each co-agent chose either money and stock, with stock being slightly more influential, interaction *Role x Money Choice*: $F(1, 88) = 381.58, p < .001, \eta_p^2 = .81$, interaction

Role x Stock Choice: $F(1, 88) = 408.75, p < .001, \eta_p^2 = .82$, interaction *Money Choice x Stock Choice*, $F(1, 88) = 31.67, p < .001, \eta_p^2 = .26$, interaction *Role x Money Choice x Stock Choice*, $F(1, 88) = 18.89, p < .001, \eta_p^2 = .18$ (see *Figure 2B*). All other effects were non-significant ($ps > .25$). Participants were further asked to judge whether they attributed the causation of the outcome more to themselves (self-agency), to both agents jointly (joint-agency), or to the co-agent (other-agency). Throughout the experiment, all participants attributed the causation of the action outcome (wins or losses) to both agents (joint agency). However, supervisors showed a tendency to attribute action outcomes more to themselves than to their co-agents, $M = 53.62, t(44) = 6.18, p < .001, d = 0.92$, whereas subordinates did not, $M = 49.69, |t|(44) = 0.51, p = .615, |d| = 0.08$ (t tests against 50 “joint agency”; see *Figure 2C*).

Interestingly, mean causation ratings were not associated with mean outcome across trials, neither for supervisors, nor for subordinates, *supervisors*: $r = .13, p = .399, 95\% \text{ CI } [-.17; .41]$, *subordinates*: $r = .08, p = .596, 95\% \text{ CI } [-.22; .37]$. Likewise, valence of outcome did not affect the participants’ causation ratings, $F(2, 176) = 1.43, p = .243, \eta_p^2 = .02, \epsilon = 0.93$ (Greenhouse-Geisser [GG] corrected), and there was no systematic difference in how supervisors and subordinates rated perceived causation for different outcome valence, $F(2, 176) = 2.13, p = .126, \eta_p^2 = .02, \epsilon = 0.93$ (GG-corrected; see *Figure 2D*).

Perceived Responsibility

The participants’ sense of responsibility ratings mirrored the causation ratings closely. Supervisors again reported higher perceived responsibility for the outcome, $F(1, 88) = 33.77, p < .001, \eta_p^2 = .28$, with the effect being even more pronounced than for causation ratings (see *Figure 2E*; see *Supplementary Table 4* for an overview of results). The participants’ sense of responsibility was strongly mediated by situational factors, i.e., participants perceived their responsibility higher when their actual control over the situation was higher, *Role x Money Choice*: $F(1, 88) = 288.06, p < .001, \eta_p^2 = .77$, interaction *Role x Stock Choice*: $F(1, 88) = 326.80, p < .001, \eta_p^2 = .79$, interaction *Money Choice x Stock Choice*, $F(1, 88) = 17.02, p < .001, \eta_p^2 = .16$, interaction *Role x Money Choice x Stock Choice*, $F(1, 88) = 44.21, p < .001, \eta_p^2 = .33$ (see *Figure 2F*). The main effects *Money Choice* and *Stock Choice* did not reach significance, *Money Choice*: $F(1, 88) = 3.12, p = .081, \eta_p^2 = .03$, *Stock Choice*: $F(1, 88) = 3.59, p = .061, \eta_p^2 = .04$. Interestingly, participants generally tended to perceive too much responsibility throughout the experiment, with a combined responsibility score of over 100, $M = 111.70, t(44) = 7.59, p < .001, d = 1.13$ (t test against 100 “maximum responsibility”). As for causation ratings, participants also attributed the responsibility for the action outcome to both agents (joint responsibility), but supervisors again showed a slight tendency to attribute the responsibility more to themselves than to the other agent, $M = 55.53, t(44) = 6.10, p < .001, d = 0.91$, whereas subordinates did not, $M = 49.15, |t|(44) = 1.27, p = .211, |d| = 0.19$ (t tests against 50 “joint agency”; see *Figure 2G*).

As with causation ratings, responsibility ratings were not associated with mean outcome across trials, for neither role, *supervisors*: $r < .01, p = .979, 95\% \text{ CI } [-.29; .30]$, *subordinates*: $r = -.03, p = .860, 95\% \text{ CI } [-.32; .27]$. Valence of outcome did not affect perceived responsibility significantly, $F(2, 176) = 2.49, p = .086, \eta_p^2 = .03$, and we found no clear, statistical difference between roles in their perception of responsibility across different outcomes, $F(2, 176) = 2.95, p = .055, \eta_p^2 = .03$ (see *Figure 2H*).

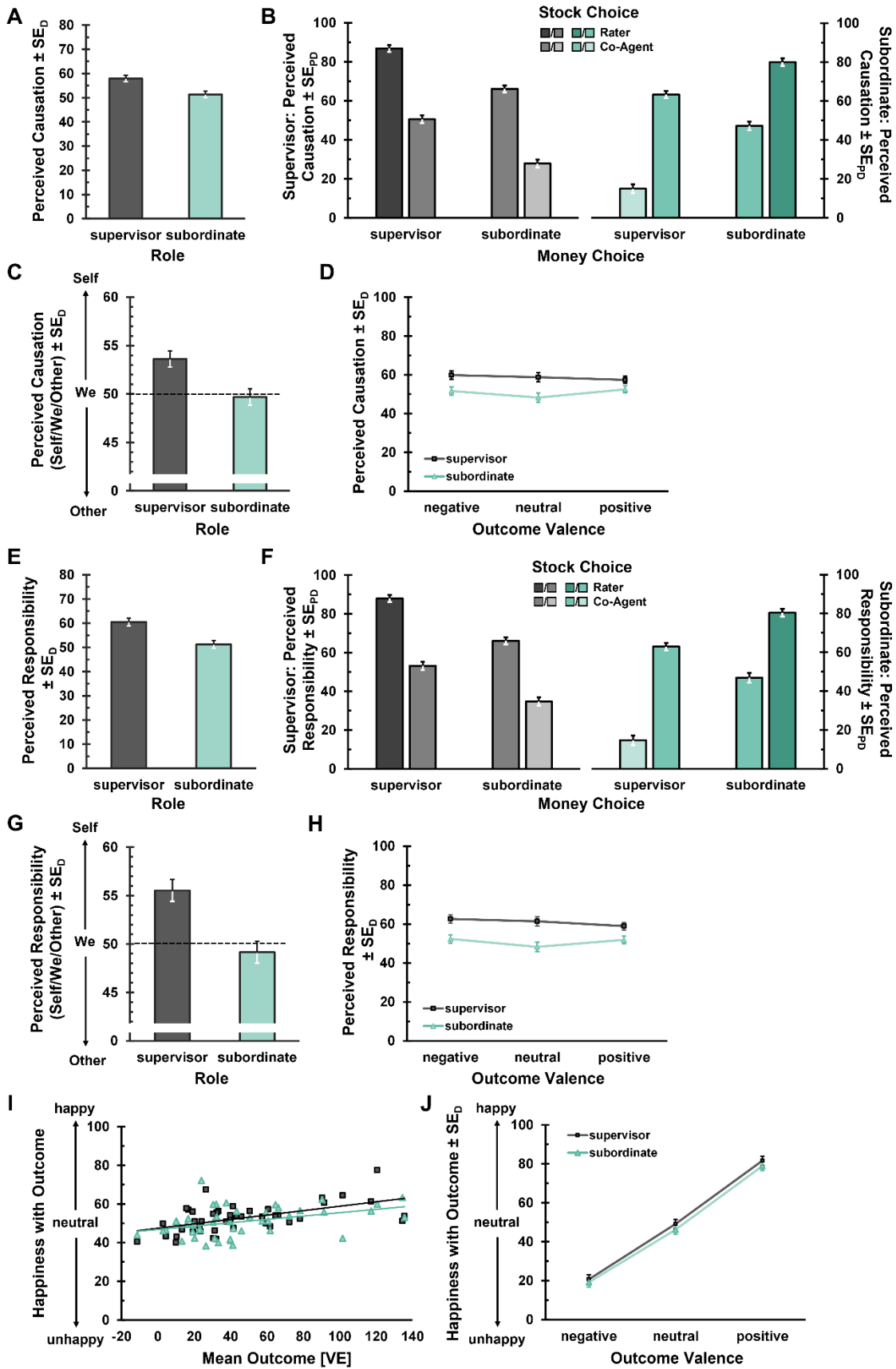


Figure 2. Results of Experiment 1. A. The participants' perceived causation of the outcome dependent on role. Supervisors tended to perceive stronger causation than subordinates despite the similarity of their possible action decisions and executions. *B.* The participants' perceived causation of the outcome, separately for each condition. The participants' actual control is mirrored in their causation ratings. The darker color of any bar pairs signifies stock choice as the rater's. Darker colors within this panel generally represent more control for the rater. *C.* Attribution of perceived causation (self/we/other). Supervisors tended to attribute causation more to themselves than to their co-agent, subordinates did not. *D.* The participants' perceived causation dependent on outcome valence. The outcome did not affect perceived causation, for either role. *E.* The participants' perceived responsibility over the outcome dependent on role. Similar to perceived causation, supervisors tended to perceive stronger causation than subordinates. *F.* The participants' perceived responsibility over the outcome, separately for each condition. The participants' actual control is mirrored in their responsibility ratings. Darker colors represent more control for the rater. *G.* Attribution of perceived responsibility (self/we/other). Supervisors tended to attribute responsibility more to themselves than to their co-agent, subordinates did not. *H.* The participants' perceived causation dependent on outcome valence. Outcome valence affected perceived responsibility only to a very small degree. *I.* Positive association of the participants' mean happiness with outcome (HWO) ratings with the mean outcome in virtual Euros (VE) at the end of the experiment. *J.* The participants' HWO ratings dependent on outcome valence. Error bars depict standard error of the difference between roles (SE_D , between-subjects) or standard error of paired differences for money choice (separately for each stock choice and role condition; SE_{PD} , within-subjects).

Happiness with Outcome

In general, neither the participants' role, nor the participants' actual control affected their happiness with the outcome (HWO), all F s < 2.25, all p s > .136 (see *Supplementary Table 5* for an overview of results). The sole exception lay with the interaction *Role x Stock Choice*, $F(1, 88) = 6.57$, $p = .012$, $\eta_p^2 = .07$, which interestingly revealed that supervisors seemed to be happiest with the trial outcome when subordinates decided on the stock, not themselves, $M_{Diff} = 4.07$, $t(44) = 2.52$, $p = .015$, $d_z = 0.38$, whereas subordinates did not show such a tendency, $M_{Diff} = -1.06$, $|t|(44) = 0.89$, $p = .376$, $|d_z| = 0.13$.

Not surprisingly, happiness with outcome was mostly influenced by the actual outcome of the trial, with a strong association of outcome and happiness with outcome for both *supervisors*: $r = .55$, $p < .001$, 95% CI [.30; .73], *subordinates*: $r = .41$, $p = .006$, 95% CI [.13; .62]. Likewise, valence of outcome showed a strong influence on HWO ratings, $F(2, 176) = 668.24$, $p < .001$, $\eta_p^2 = .88$, $\varepsilon = 0.83$ (GG-corrected). In contrast, role did not affect HWO ratings significantly, $F(1, 88) = 3.19$, $p = .078$, $\eta_p^2 = .03$. Likewise, role and valence of outcome did not interact in their impact on HWO ratings, $F(2, 176) = 0.10$, $p = .902$, $\eta_p^2 < .01$, $\varepsilon = 0.83$ (GG-corrected, see *Figure 2I-J*).

Control Analysis: Learning Effects

Our experimental design did not give overt cues as to how stocks would develop in the next trial; nevertheless, because stock development was balanced overall, participants could learn how to produce positive results, thus changing the procedure from a game of luck towards a game of skill. As such a difference could potentially influence the participants' perceived causation, perceived responsibility, and happiness with outcome, we checked for the participants' learning progress throughout the experiment. As positive and negative outcomes were equally likely, we tested whether (1) participants learned overall and (2) whether positive outcomes were more likely towards the later parts of the experiment. Indeed, participants finished with a mean total of 3901 VE, indicating that they did learn how to produce positive results, $t(44) = 11.44$, $p < .001$, $d = 1.70$ (tested against zero) with all participant pairs finishing with a positive outcome. When categorizing the trials into different quantiles of 21 trials each, the data indicates no difference in outcome between quantiles, as the outcome proved very positive from the first quantile on, $F(3, 132) = 0.67$, $p = .573$, $\eta_p^2 = .02$. Learning thus seems to have occurred so early that throughout the experiment, the levels of outcome no longer changed.

Experiment 1: Discussion

In this experiment, we investigated how roles – even in situations of almost similar degrees of freedom across these roles – may affect perceived causation (as our sense of agency measure), perceived responsibility, and happiness with outcome (HWO). We tested how situational changes in actual control affected these measures, and how the actual outcome (which related to changes in actual monetary reward at the end of the experiment) affected participants' sense of agency. Furthermore, we evaluated whether perceived responsibility and perceived control are conceptualized similarly or differently across participants, as well as how sense of agency relates to happiness with outcome. We also incorporated attribution ratings that allowed participants to decide whether or not they attributed causation and responsibility more to themselves, to the pair as a joint entity, or to the other agent. Finally, we analyzed how action outcome relates to sense of agency, sense of responsibility, and happiness with outcome in this scenario.

One of the most interesting findings in Experiment 1 is certainly that perceived causation was not affected by outcome valence, differently from expected. That is, whether or not a pair gained or lost virtual money by their investment did not impact the participants' sense of agency for that investment. Furthermore, our data clearly show that, in accordance with our expectations, supervisors perceived more causation than subordinates, and tended to attribute causation more strongly to themselves than subordinates. Actual control was reflected in the participants' ratings, with rating being highest when all decisions lay with the rater, lowest, when all decisions lay with the co-agent, and medium, when decisions were split between both participants. Note that stock choice affected perceived causation more strongly than money choice, possibly due to the fact that stock choice could be construed a stronger determining factor on valence of outcome, whereas money choice determined the magnitude of that outcome. Moreover, stock choice was the last choice and thus the final decider in any trial.

These findings were mirrored by the perceived responsibility of the participants: perceived responsibility ratings show a similar result pattern as perceived causation ratings in most instances, suggesting that causation and responsibility are similarly conceptualized in participants, $r = .79$, $p < .001$, 95%CI [.70; .86]. As such, supervisors also perceived more responsibility than subordinates, and tended to attribute responsibility more to themselves than to subordinates.

Interestingly, both involved agents firmly perceived their actions as a joint venture with both agents sharing causation and responsibility. While the difference between roles was highly systematic across pairings, supervisors only deviated about 5% from a perfect joint causation or joint responsibility score as (almost) shown by subordinates. This indicates that, across conditions, participants were strongly aware of both parties' contributions to the outcomes of their investments. However, the supervisors' responses showed a stronger sensitivity to the social factor role in that they perceived a slight, but clear bias in causation and responsibility towards themselves, whereas subordinates seemed to largely ignore their role with regards to their agency attribution.

When combined, responsibility rating scores exceeded 100%, indicating a generalized overestimation of responsibility. This finding is in line with previous studies (van der Wel et al., 2012) as well as documented egocentric biases in attribution (Ross & Sicoly, 1979) indicating that participants tend to overestimate rather than underestimate responsibility in dyads. This finding stands seemingly in contrast to the diffusion of responsibility phenomenon often found in larger groups (e.g., Darley and Latane, 1968; Mynatt and Sherman, 1975) and previous evidence which suggests that the presence of another person can reduce an agent's sense of agency ratings, speaking for a diffusion of responsibility even in dyad situations (Beyer et al., 2017). Although these findings seem to directly oppose our interpretation, our results may still be well compatible with these findings, and instead characterize specific situational parameters in which sense of agency formation diverges: the overestimation of responsibility in our experiment was mainly based on the participants' ratings during co-acting, i.e., in situations in which both contributed to the action outcome, a condition which did not exist in the study by Beyer and colleagues (2017). In contrast, Beyer and colleagues (2017) inferred diffusion of responsibility by comparing participants' sense of agency when acting alone versus when acting in the presence of a co-agent which is not a comparison our study design allowed. Thus, participants may show a reduced sense of agency when acting in the presence of others, but may infer more sense of agency than warranted when co-acting with another person.

Happiness with outcome differed strongly from sense of agency and sense of responsibility ratings, all r s $< .12$, p s $> .254$. As such, HWO ratings were largely unaffected by the participants' actual control, nor their role as supervisors or subordinate. However, any effect of actual control on HWO ratings was contrary to what we originally expected: supervisors were actually happier when subordinates decided on stock not themselves, although stock choice was the more decisive choice for their sense of agency (see perceived causation ratings). This could imply that higher control could actually impair rather than increase the participants' happiness with outcome. Finally, as expected, valence of outcome was mostly affected by the actual outcome of the investment, with positive outcomes eliciting the highest and negative outcomes the lowest HWO ratings.

The setup of Experiment 1 did not allow distinguishing between action decisions and action execution in their impact on sense of agency, and we have yet to determine how the individual power to counteract direct orders may affect their sense of agency. Experiments 2 and 3 answered this question with an adapted experimental procedure.

Experiment 2-3

To disentangle action decision and action execution, Experiments 2-3 had the supervisor make all action decisions, that is, supervisors could opt to execute the action (i.e., the investment) themselves or they could decide to delegate action execution to the subordinate. While subordinates had to follow all of these orders in Experiment 2, subordinates in Experiment 3 could choose to veto the supervisor's decisions in up to 20% of trials in which they executed the action. Figure 3 gives an overview of this setup.

Experiment 2-3: Methods

Participants

We recruited 106 participants in same-sex pairs (Experiment 2: $N = 54$; mean age = 24.6 years, range 18-67; 44 females, 10 males; 46 right-handed, 8 left-handed; Experiment 3: $N = 52$; mean age = 25.3 years, range 18-59; 40 females, 12 males; 45 right-handed, 7 left-handed). As in Experiment 1, the starting roles in each pair were randomly assigned at the beginning of the experiment. However, in contrast to Experiment 1, after half of the experiment, the participants switched roles, allowing us to test the factor Role also as a within-subjects factor. We collected demographics data by asking participants about their sex/gender (please note that German does not differentiate between both concepts) with options being "female" and "male". We did not include a non-binary option because participants were specifically recruited as either "female" or "male" to form same-sex pairings for the experiments. Participants were asked about their handedness by giving the options "right-handed", "left-handed", and "ambidextrous". Participants gave their age by writing a number into the response box.

Experiment 1 indicated that effect sizes for our main analyses (the impact of role and of actual control on sense of agency) were large with d s > 1.0 . However, as the experimental setup and hierarchical relationship between supervisor and subordinate was altered in Experiment 2 and 3, we opted to calculate our sample size with a reduced effect size of $d = 0.6$ instead plus an additional 15% to compensate for possible dropouts, resulting in a minimum sample size of $N = 52$ per experiment, to allow for between-experiment comparisons. As we did not have to exclude any participants, our final sample size of $N = 106$ participants allowed a power of $1-\beta = 0.80$ for all $d > 0.55$ for between-experiment comparisons and all $d_z > 0.27$ for within-subjects comparisons. Participants gave informed consent prior to the experiment and received monetary compensation for participation.

Apparatus

The experimental setup was the same as in Experiment 1 with one exception: in Experiments 2 and 3, supervisors and subordinates interacted verbally in a structured manner. That is, in conditions in which supervisors chose the subordinates to execute the investment decision, supervisors instructed the subordinates verbally as to which investments they were supposed to undertake and the subordinates could either respond with "understood!" or ask for clarification. The wording of these verbal interactions was instructed to ensure identical interactions across participant pairs. No other verbal interaction between participants took place.

Procedure

Participants were instructed similarly as in Experiment 1 with regards to the general task and procedure of the experiment. In contrast to Experiment 1, however, they were informed that supervisors would always decide on the amount of money to be invested and the funds in which it would be invested, but that the supervisors could decide whether they would execute the investment themselves or would delegate the investment to subordinates. Participants were told that both, supervisors and subordinates, would be asked to rate, for example, their perceived causation of the outcome, and they were asked to respond as honestly as possible. Finally, as in Experiment 1, they were told that if they (and their co-agent) drew a profit at the end of the experiment, this would be rewarded by an additional monetary compensation of up to 5 Euros depending on the size of the profit.

Both experiments started with a single practice trial to familiarize the participants with the procedure, followed by a first phase 42 experimental trials in Experiment 2 and 30 experimental trials⁵ in Experiment 3. Participants were then asked to switch roles (they were not told about this role switch before this point in time) and completed the same number of trials with switched roles (including the initial practice trial).

Figure 3 shows the trial procedure. The supervisor started the trial by deciding which participant (supervisor or subordinate) would execute the investment. Although supervisors could make that decision, a counter on the monitor told them how often they were still allowed to make certain choices, resulting in a final 21 trials for each condition (15 trials per condition in Experiment 3): (1) investment decisions: supervisor; investment execution: supervisor (2) investment decisions: supervisor, investment execution: subordinate. The supervisor was then prompted to choose the amount of money to be invested and the fund in which the money was to be invested by either putting in numbers via the keyboard or by instructing the subordinate verbally on his/her decisions so that the subordinate would put in the numbers via the keyboard. If the numbers exceeded the allowed range (1000 VEs; stock numbers 1-3) an error message occurred, and they were asked to input their response again. Both participants then saw on their monitors the amount of money and the fund chosen and supervisors were asked if the investment reflected their choices. In Experiment 2, if the supervisors pressed no, the subordinate had to input the investment again. The subordinate thus had to follow the supervisor's instructions. The remainder of the trial, except for the ratings, was as in Experiment 1: Ratings were given in 11 trials of each condition (Experiment 2) or 7-10 trials per condition (depending on veto trials in Experiment 3) and were provided on only three scales (perceived causation, perceived responsibility, and happiness with outcome).

Experiment 3 repeated this procedure with one procedural difference: If subordinates were to execute the supervisors' decisions, they could veto the decision of the supervisors in up to 3 out of the 15 trials. The veto option always affected the whole investment decision, and, if taken, subordinates could freely decide whether they wanted to change one or both of the supervisors' choices. As long as this option remained, subordinates were asked in every trial of this condition if they wanted to exercise their veto right or not. If so, they could make a different

⁵ We reduced the number of trials due to time restrictions because of COVID19-related safety procedures.

investment and supervisor and subordinate were then informed as to the actual investment the subordinate initiated. Supervisors could always indicate if a selection reflected their own decisions; if not and the veto rights were already exhausted, subordinates were then prompted to input the actual choices of the supervisor. This procedure was intended to ensure that supervisors still exercised control apart from the potential three veto trials. Veto trials were always rated by both participants.

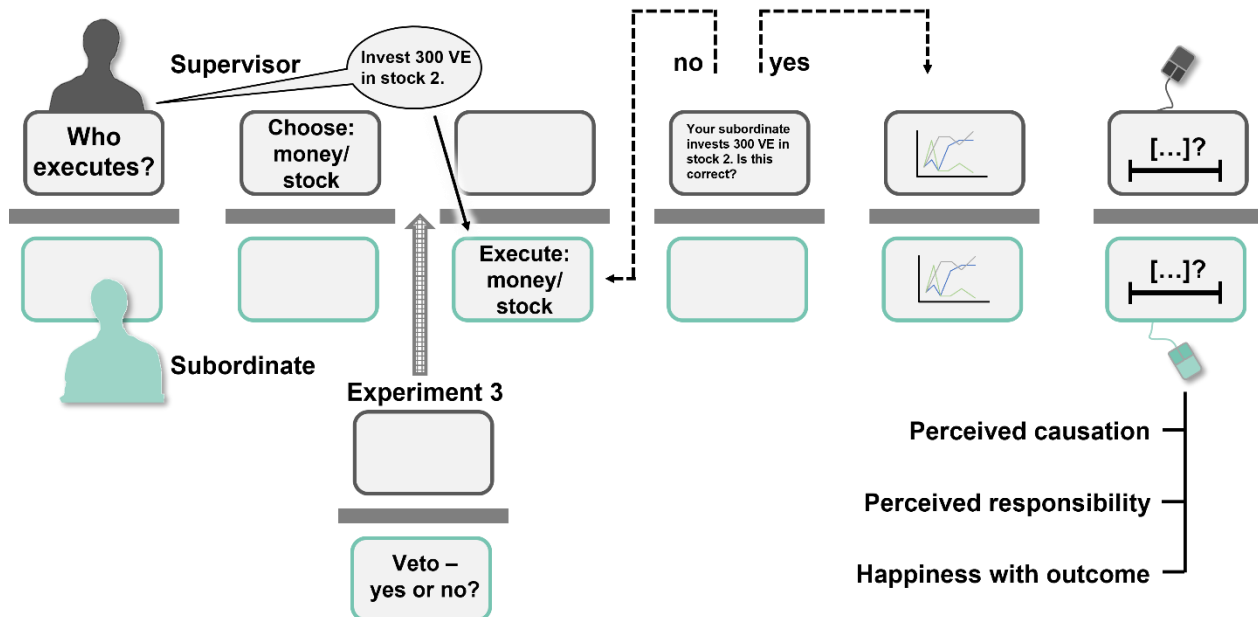


Figure 3. Trial Procedure of Experiments 2 and 3. The depicted trial has the superordinate delegate action execution to the subordinate. In *Experiment 2*, supervisors (dark grey) were asked to decide which participant would execute the action (investment); a displayed counter ensured that each of the two possible conditions was picked equally often. Either supervisors or subordinates (light turquoise) were then asked to input the amount of money that would be invested and the stock number in which the money would be invested. If the subordinate was to execute the action, the supervisor gave the order to invest verbally according to a predetermined script. After action execution, the supervisor was able to assess whether the investment was executed correctly. If not, the subordinate had to correct the action execution (dotted arrow). Action execution was followed by a visualization of the stock development for each fund. In a subset of trials, both participants were asked to rate their sense of agency of three scales: perceived causation, perceived responsibility, and happiness with outcome. In *Experiment 3*, trial procedure was largely the same; however, if subordinates executed the action (condition 2), they had the option to veto the supervisor's decisions in 20% of trials and they were asked if they wished to veto the supervisor's decisions once per trial until all veto options were exhausted. Dotted arrows signify trial procedures occurring only if no veto options are available (i.e., throughout *Experiment 2*, and in *Experiment 3* after all veto options are exhausted).

Data Analysis

Perceived Causation and Responsibility

To probe for the participants' perceived causation and responsibility, we conducted an ANOVA with the within-subjects factors *Role* and *Execution* as well as the between-subjects factor *Experiment* for both ratings and calculated follow-up *t*-tests if necessary. As in Experiment 1, we further categorized the outcome into three valence levels: negative (losses of more than 50 VE), neutral (wins or losses of less than 50 VE), and positive (wins of more than 50 VE) and then calculated an ANOVA with the within-subjects factors *Role* and *Valence of Outcome* as well as the between-subjects factor *Experiment*. Because of subtle differences in rating patterns between perceived causality and perceived responsibility, we added a post-hoc ANOVA including the type of rating as an additional within-subjects factor *Rating Type* (perceived causation vs. perceived responsibility). For all analyses we adopted an alpha-error-level of 5%.

Happiness with Outcome

For analysis of HWO ratings, we conducted an ANOVA with the between-subjects factor *Experiment* and the within-subjects factors *Role and Action Choice*. For analysis of the impact of outcome valence, we additionally conducted an ANOVA with the between-subjects factor *Experiment* and the within-subjects factors *Role and Valence of Outcome*.

Veto Power: Situational vs. Sustained

Due to the low number of veto trials (0-3 ratings per participant) and the resulting unreliability of statistical analyses, we chose not to include veto as a situational factor. Instead, to probe whether the impact of veto power was situational, i.e., restricted to the instances of veto assertion, or sustained, i.e., impacting non-veto trials as well, we conducted all previously detailed analyses without veto trials, and analyzed the impact of the between-subjects factor *Experiment* without veto trials. Furthermore, to ensure that the ratings in which all veto options were already exhausted did not affect this analysis substantially, we repeated all analyses but also excluded ratings with all vetoes exhausted from the analysis.

Control Analysis: Learning Effects

As in Experiment 1, we looked for potential learning effects by testing the mean total of outcome against zero in one-sample *t*-test, separately for each block, i.e., for each role combination. We further categorized trials into two quantiles (quantile 1 = trials 1-21, quantile 2 = trials 22-42 for Experiment 2; quantile 1 = trials 1-15, quantile 2 = trials 16-30 for Experiment 2), and calculated an ANOVA with the within-subjects factor quantile to evaluate whether outcome changed across different quantiles. We then re-calculated all ratings (perceived causation, perceived responsibility, and happiness with outcome) with the additional within-subjects factor *Quantile* to evaluate whether ratings changed over time in accordance with a potential learning effect.

Transparency and Openness

The data and analysis scripts for Experiments 2 and 3 are publicly accessible on the Open Science Framework (osf.io/hjvxp/). Both experiments were preregistered; the preregistrations are available on the Open Science Framework (Exp. 2: osf.io/zum8y, Exp. 3: osf.io/zsj3u).

Experiment 2-3: Results

Figure 4 summarizes the main findings of both experiments, particularly in terms of perceived causation and happiness with outcome. Detailed descriptive data relating to perceived responsibility is reported in Figure S1 in the Supplementary Material.

Supplementary Tables 6-11 summarize the main analyses for perceived causation, perceived responsibility, happiness with outcome, veto power, and learning effects.

Perceived Causation

Role had a substantial impact on perceived causation across both experiments, $F(1, 104) = 627.06$, $p < .001$, $\eta_p^2 = .86$, with supervisors reporting higher causation than subordinates (see *Supplementary Table 6* for an overview of results). However, veto power reduced this influence of role, interaction *Role x Experiment*, $F(1, 104) = 7.77$, $p = .006$, $\eta_p^2 = .07$. Interestingly, when subordinates executed the action (i.e., when action decision and action execution were separated) perceived causation was generally higher, main effect *Execution*, $F(1, 104) = 65.47$, $p < .001$, $\eta_p^2 = .39$. Moreover, perceived causation ratings increased strongly if decisions were implemented by the rater, interaction *Role x Execution*, $F(1, 104) = 196.14$, $p < .001$, $\eta_p^2 = .65$, indicating that action execution also plays a vital role in determining sense of agency in any agent, not only the action decision. Even without veto power (Experiment 2), the supervisors' perceived control decreased and the subordinates' perceived control increased when subordinates rather than supervisors executed the investment, supervisor rating: $M_{Diff} = 4.11$, $t(53) = 4.55$, $p < .001$, $d_z = 0.62$, subordinate rating: $M_{Diff} = -17.75$, $|t|(53) = 6.69$, $p < .001$, $|d_z| = 0.91$. This difference in perceived causation was even more pronounced when veto power was introduced into the paradigm (Experiment 3), supervisor rating: $M_{Diff} = 13.70$, $t(51) = 8.76$, $p < .001$, $d_z = 1.22$, subordinate rating: $M_{Diff} = -31.18$, $|t|(51) = 10.66$, $p < .001$, $|d_z| = 1.48$.

This difference was supported by a significant three-way interaction *Role x Execution x Experiment* which provided further evidence that veto power affected the interaction of role and action execution, $F(1, 104) = 23.34$, $p < .001$, $\eta_p^2 = .18$ (see Figure 4A). Follow-up analyses revealed that veto power reduced the perceived causation of supervisors and increased the perceived causation of subordinates when subordinates held veto power, supervisor ratings, action execution: subordinate (Experiments 2-3), $M_{Diff} = 12.24$, $t(104) = 3.45$, $p < .001$, $d = 0.67$; subordinate ratings, action execution: subordinate (Experiments 2-3), $M_{Diff} = -12.07$, $|t|(104) = 2.66$, $p = .009$, $|d| = 0.52$. Generally, however, average ratings did not differ significantly between experiments, $F(1, 104) = 0.17$, $p = .677$, $\eta_p^2 < .01$, nor did the impact of action execution, interaction *Execution x Experiment*, $F(1, 104) = 1.00$, $p = .320$, $\eta_p^2 = .01$.

As in Experiment 1, valence of outcome did not play a big part in determining perceived causation, $F(2, 196) = 2.50$, $p = .085$, $\eta_p^2 = .02$, and there was no systematic difference in how supervisors and subordinates rated perceived causation for different outcome valences, interaction *Role x Valence of Outcome*, $F(2, 196) = 0.63$, $p = .532$, $\eta_p^2 = .01$, or how valence of outcome affected perceived causation across experiments, interaction *Valence of Outcome x Experiment*, $F(2, 196) = 0.43$, $p = .650$, $\eta_p^2 < .01$. However, a significant three-way interaction *Role x Valence of Outcome x Experiment* indicates that valence of outcome might slightly affect the interaction of role and veto power, $F(2, 196) = 3.32$, $p = .038$, $\eta_p^2 = .03$ (see Figure 4B), with the strongest influence of veto power on the impact of role on perceived causality for negative outcome values.

Perceived Responsibility

Mirroring the results of the perceived causation ratings, role proved to be a decisive factor in the participants' perceived responsibility ratings, $F(1, 104) = 681.26$, $p < .001$, $\eta_p^2 = .87$, with supervisors reporting higher responsibility than subordinates (see Figure S1A; see Supplementary Table 7 for an overview of results). Again, veto power reduced this influence of role, interaction *Role x Experiment*, $F(1, 104) = 7.38$, $p = .008$, $\eta_p^2 = .07$. A separation of action decision (by the supervisor) and action execution (by the subordinate) generally lead to an increased sense of responsibility, main effect *Execution*, $F(1, 104) = 81.07$, $p < .001$, $\eta_p^2 = .44$. Sense of responsibility also increased if the rater executed the action, interaction *Role x Execution*, $F(1, 104) = 171.35$, $p < .001$, $\eta_p^2 = .62$, again indicating that sense of responsibility is sensitive as to who executes the action and not only to the action decision itself. Veto power affected this interaction of role and action execution resulting in a significant three-way interaction *Role x Execution x Experiment*, $F(1, 104) = 24.30$, $p < .001$, $\eta_p^2 = .19$. That is, even without veto power (Experiment 2), the supervisors' perceived responsibility decreased and the subordinates' perceived responsibility increased when subordinates rather than supervisors executed the investment, supervisor rating: $M_{Diff} = 1.87$, $t(53) = 2.48$, $p = .016$, $d_z = 0.34$, subordinate rating: $M_{Diff} = -17.62$, $|t|(53) = 6.81$, $p < .001$, $|d_z| = 0.93$. Please note, however, that the decrease in the supervisors' perceived responsibility ratings was much lower than for perceived causation ($d_z = 0.62$ for perceived causation and $d_z = 0.34$ for perceived responsibility; see Figure 4C). The difference in perceived responsibility due to action execution was even more pronounced when veto power was introduced into the paradigm (Experiment 3), supervisor rating: $M_{Diff} = 12.46$, $t(51) = 9.04$, $p < .001$, $d_z = 1.25$, subordinate rating: $M_{Diff} = -30.58$, $|t|(51) = 9.94$, $p < .001$, $|d_z| = 1.38$ (see Figure S1A). All other effects were non-significant, $F_s < 0.40$, $p_s > .529$.

The subtle differences in the rating patterns between perceived causation and perceived responsibility led us to analyze the difference between both rating types further. Indeed, an ANOVA including *Rating Type* as a factor revealed that rating patterns differed between perceived causation and perceived responsibility, $F(1, 104) = 4.36$, $p = .039$, $\eta_p^2 = .04$, with responsibility ratings being generally slightly higher, although the difference between both was only about 1% of the scale.

Valence of outcome did not strongly affect perceived responsibility, $F(2, 196) = 2.56$, $p = .080$, $\eta_p^2 = .03$, similar to rating patterns of perceived causation. These results suggest that outcome has little to no influence on either role's perceived responsibility within this setting.

Happiness with Outcome

Across both experiments, subordinates were happier with the outcome of their action choices than supervisors (see Figure 4D); main effect *Role*, $F(1,104) = 9.16$, $p = .003$, $\eta_p^2 = .08$, $M_{Supervisor} = 47.07$, $M_{Subordinate} = 51.45$ (see *Supplementary Table 8* for an overview of results). Generally, veto power increased happiness with outcome, main effect *Experiment*, $F(1,104) = 7.32$, $p = .008$, $\eta_p^2 = .07$, $M_{Exp2} = 47.45$, $M_{Exp3} = 51.14$. A numerical difference was present in that holding more control seemed to detract from happiness with outcome, but this difference was not significant, $F(1, 104) = 3.52$, $p = .063$, $\eta_p^2 = .03$, and $F(1, 104) = 3.04$, $p = .084$, $\eta_p^2 = .03$. All other effects were non-significant with $F_s < 1.96$ and $p_s > .165$.

As in Experiment 1, happiness with outcome was mostly affected by the actual outcome of the investment; main effect *Valence of Outcome*, $F(2, 196) = 685.01$, $p < .001$, $\eta_p^2 = .88$, $\epsilon = 0.68$ (GG-corrected; see Figure 4E). However, irrespective of actual outcome (and veto power), subordinates still were generally happier with outcome than supervisors, $F(1, 98) = 10.78$, $p = .001$, $\eta_p^2 = .10$. This was especially the case for negative and neutral outcomes, whereas for positive outcomes, subordinates and supervisors were equally content with the result of the investment; interaction *Role x Valence of Outcome*, $F(2, 196) = 7.15$, $p = .001$, $\eta_p^2 = .07$. Across all outcome levels, role impacted participants' HWO ratings more strongly in Experiment 2 than in Experiment 3, interaction *Role x Experiment*, $F(1, 98) = 5.29$, $p = .024$, $\eta_p^2 = .05$, i.e., whereas subordinates were generally happier with outcomes than supervisors without veto power, the introduction of veto power decreased this difference by elevating the supervisors' HWO ratings (see Figure 4F). All other effects were non-significant with $F_s < 2.48$ and $p_s > .118$.

Veto Power: Situational or Sustained Impact?

Finally, we conducted all analyses without the veto trials themselves to probe whether the impact of veto power is situational, i.e., limited to the instances of veto assertion themselves, or sustained, i.e., affecting all trials in the respective condition. If veto power were sustained, the between-subjects factor *Experiment* should still affect perceived causation, perceived responsibility, and HWO ratings. If not, the impact of the between-subjects factor *Experiment* should be negligible (see *Supplementary Table 9* for an overview of results).

Indeed, for perceived causation and perceived responsibility ratings, the factor *Experiment* lost its impact without the veto trials themselves, signifying that for these concepts, the impact of veto power is limited to the actual situation in which the subordinates veto the supervisor's decisions. This is especially interesting, as a closer look at the veto data shows that only 42% of the participants ($N = 22$) chose to use all three veto options which indicates that most participants could have vetoed any decision by the supervisor until the end of the experiment if they so chose. Indeed, only 9.4% of all ratings for subordinate-executed actions in Experiment 3 were given with all veto options exhausted, resulting in over 90% over the measured ratings given with veto power still intact.

In contrast to perceived causation and perceived responsibility, happiness with outcome seemed susceptible to the impact of veto power in a more sustained fashion, with a significant increase in HWO ratings in Experiment 3 compared to Experiment 2 across all participants, main effect *Experiment*, $F(1,104) = 9.40$, $p = .003$, $\eta_p^2 = .08$.

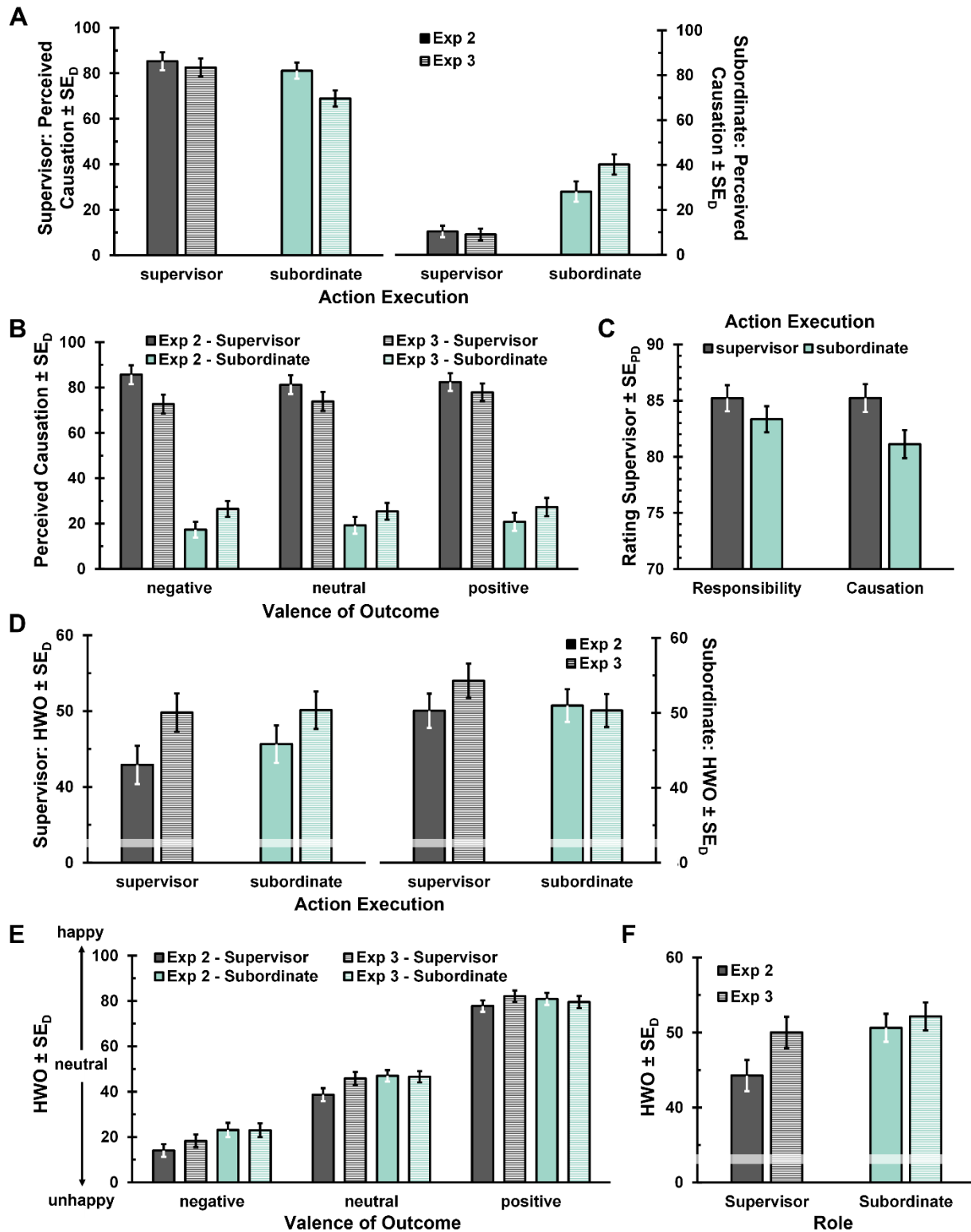


Figure 4. Main results of Experiments 2 and 3. Results of Experiment 2 are colored solid, results of Experiment 3 are displayed in striped bars. A. The participants' perceived causation of the outcome dependent on role and action execution. Both, role (i.e., action decisions) and action execution, impacted the participants' perceived causation ratings. B. The participants' perceived

causation dependent on outcome valence. *C.* The impact of action execution on the supervisors' ratings for perceived causation and perceived responsibility. *D.* The participants' mean happiness with outcome (HWO) dependent on role, action execution, and veto power (Experiment). Subordinates were generally happier with outcome than supervisors. Likewise, veto power increased HWO ratings across all participants. *E.* The participants' mean happiness with outcome dependent on outcome valence, role, and veto power (Experiment). Outcome valence affected HWO ratings to a very strong degree. *F.* The participants' mean happiness with outcome dependent on role and veto power (factor *Experiment*). Veto power increased happiness with outcome especially in supervisors. Error bars depict standard error of the difference between experiments (SE_D , between-subjects) or standard error of the paired difference between roles (SE_{PD} , within-subjects).

To ensure that the ratings in which all veto options were already exhausted did not affect this analysis significantly, we repeated all analyses but excluded these ratings from the analysis (see *Supplementary Table 10* for an overview of results). Results were largely the same; however, we found a small effect of Experiment on the interaction Role x Valence of Outcome for perceived causation, interaction *Experiment x Role x Valence of Outcome*, $F(2, 184) = 3.21$, $p = .043$, $\eta_p^2 = .03$, which shows that whereas subordinates perceived a slight increase in causation with increasing valence of outcome in Experiment 2, this was no longer the case once veto options were introduced, with subordinates perceiving least causation for neutral outcomes. A more pronounced difference emerged for HWO ratings when supervisors executed the action: Without veto power, the supervisors were slightly less happy with the action outcome than the subordinates, but this pattern reversed when veto power was introduced with supervisors being happier with action outcome than subordinates, interaction *Execution x Experiment*, $F(1, 100) = 5.11$, $p = .026$, $\eta_p^2 = .05$.

Control Analysis: Learning Effects

For Experiment 2, we found no effect of learning over time as in Experiment 1. Participants finished with a mean total of 1091 VE for the first block, and a mean total of 1118 VE for the second block with switched roles. Both outcomes significantly differ from zero, indicating that participants learned how to produce positive results, Block 1: $t(26) = 4.23$, $p < .001$, $d = 0.81$, and $t(26) = 4.71$, $p < .001$, $d = 0.91$. Only 5 pairs in the first block and 3 pairs in the second block finished with negative overall outcomes. When categorizing the trials into two quantiles of 21 trials each, the data indicates no difference in outcome between quantiles, as the outcome again proved very positive from the first quantile on, $F(1, 26) = 0.32$, $p = .579$, $\eta_p^2 = .01$. Learning thus seems to have occurred so early that throughout either block, the levels of outcome no longer changed.

For Experiment 3, the results of the analysis differ from Experiments 1 and 2, possibly due to the fewer trials in the experiment. Participants finished with a mean total of 678 VE for the first block, and a mean total of 1187 VE for the second block with switched roles. Both outcomes significantly differ from zero, indicating that participants learned how to produce positive results, Block 1: $t(25) = 3.82$, $p < .001$, $d = 0.74$, and $t(25) = 4.84$, $p < .001$, $d = 0.95$. Only 5 pairs in the

first block and 2 pairs in the second block finished with negative overall outcomes. When categorizing the trials into two quantiles of 15 trials each, the data show an effect of order in that outcomes in the first quantile were smaller than in the second, $F(1, 25) = 5.90$, $p = .023$, $\eta_p^2 = .19$. Participants thus seemed to have even improved their understanding on how to produce positive results throughout the experiment.

We followed this analysis up by looking into the effects of this learning process on perceived causation, perceived responsibility, and HWO scores. The main factor *Quantile* did not affect the participants' causation ratings, $F(1, 51) = 1.92$, $p = .172$, $\eta_p^2 = .04$. However, the interaction *Role x Quantile* showed that supervisors and subordinates seemed to be differently affected, as the supervisors' perceived causation ratings slightly increased and the subordinates perceived causation ratings slightly decreased over time, $F(1, 51) = 17.18$, $p < .001$, $\eta_p^2 = .25$. The perceived responsibility ratings mirror these results precisely, main effect *Quantile* $F(1, 51) = 0.05$, $p = .829$, $\eta_p^2 < .01$, interaction *Role x Quantile*, $F(1, 51) = 16.34$, $p < .001$, $\eta_p^2 = .24$. Interestingly, HWO scores also slightly increased with *Quantile*, $M_{Diff} = 4.10$, $F(1, 51) = 4.54$, $p = .038$, $\eta_p^2 = .08$, but no interaction effect with role emerged, *Role x Quantile*, $F(1, 51) = 0.30$, $p = .864$, $\eta_p^2 < .01$.

To probe whether learning effects could account for these results, we included the data of Experiment 2 into the analysis (see *Supplementary Table 11* for an overview of results). The effects of the learning process on perceived causation and perceived responsibility as described before were confirmed by a significant three-way interaction for both rating types, perceived causation: interaction *Experiment x Role x Quantile*, $F(1, 104) = 8.82$, $p = .004$, $\eta_p^2 = .08$, perceived responsibility: interaction *Experiment x Role x Quantile*, $F(1, 104) = 9.86$, $p = .002$, $\eta_p^2 = .09$. However, the main effect of *Quantile* for HWO scores did not differ between experiments, suggesting that this order effect might not depend on learning processes, but could rather be a general increase in happiness with outcome over time, interaction *Experiment x Quantile*, $F(1, 104) = 1.84$, $p = .178$, $\eta_p^2 = .02$.

Experiments 2-3: Discussion

The setup of Experiment 2-3 allowed us to separate action decision from action execution. A between-experiment comparison further allowed us to assess how veto options affected perceived causation, perceived responsibility, and happiness with outcome in both, higher and lower levels of hierarchy.

As in Experiment 1, we found role to be a determining factor in perceived causation and perceived responsibility; however, as the relationship between supervisors and subordinates were more unequal in Experiments 2 and 3, this effect was substantially increased. In Experiment 2, role was directly related to the power of decision making, whereas in Experiment 3, some of that power was given back to subordinates by the veto option in up to 20% of trials in which they executed the investment. Our results demonstrate that both, action decisions and action execution, determine sense of agency, with the subordinates' perceived causation and responsibility increasing significantly when they execute the action – even if they have no choice but to do so. Interestingly, the supervisors' sense of agency does not decrease proportionally to the increase of sense of agency in subordinates, as evidenced by the difference in effect size

between both comparisons for perceived causation (medium vs. large effect size). This is in line with the finding from Experiment 1 that participants tend to over- rather than underestimate their sense of agency in this scenario. Veto power for subordinates in Experiment 3 increases the impact of action execution even further. As in Experiment 1, these results were similar for perceived responsibility ratings; however, perceived responsibility remained relatively high for supervisors even when subordinates executed the investment, suggesting that while perceived causation decreases, the supervisors' sense of responsibility remains high.

One of the most interesting results in these studies concerns the participants' happiness with outcome. Whereas control or power is widely assumed to be a rewarding experience (Leotti & Delgado, 2011; Leotti et al., 2010; Lorenz et al., 2015), our participants showed markedly different tendencies: subordinates were generally happier than supervisors with the action outcome, especially in Experiment 2 in which they did not contribute any action decisions. Accordingly, while the introduction of veto power in Experiment 3 increased general happiness with outcome, it did so mainly in supervisors (and in subordinates when they did not play any part in the action process). In other words, the more positive attitude towards action outcome after the introduction of veto power did not stem from an increase in subordinates, i.e., the individuals who experienced more power and sense of agency, but from the increase in HWO ratings in supervisors who experienced less power and sense of agency in these conditions. This tendency is further corroborated by the fact that the difference between HWO ratings in supervisors and subordinates is mainly found in trials with negative or neutral outcomes; and, in fact, these low HWO scores in supervisors are then elevated when subordinates gain power through veto options.

Altogether, these results point to a picture in which higher sense of agency combined with more power in hierarchical situations lead to an increased sense of responsibility that may weigh more heavily on these participants resulting in less happiness with the achieved outcome, especially in negative and neutral outcome situations. Supervisors seem to be more critical of outcome than subordinates in these situations, possibly due to their increased sense of responsibility. Although most previous evidence suggest that choice is perceived as positive (e.g., Bown et al., 2003), there are studies that point towards the difference of *having* choices and *making* choices, with making choices being far more controversial (Barnett et al., 2008; Ogden et al., 2008), potentially because they inherently encompass the possibility of making the wrong choice. Moreover, if decisions affect not only oneself but also another person, such considerations might be even more pronounced, as social responsibility has been reported to effect decision making behavior, especially under risk (Pahlke et al., 2015). Interestingly, in more competitive situations, participants seem to tend to more selfish rather than prosocial behavior when placed in a position of more power hinting that the benign general atmosphere of the present experiments might play a role in the participants' responses (LeBars et al., 2022).

Finally, we tested whether the impact of veto power on perceived causation, perceived responsibility, and happiness with outcome was situational (i.e., limited to the occasions in which subordinates asserted their right to veto) or sustained (i.e., also coloring situations in which subordinates did not choose to veto the supervisor's decision). Our findings indicate that the increase in sense of agency and sense of responsibility in subordinates (and the respective decrease in supervisors) is largely situational and the mere option to do so does not affect perceived causation and perceived responsibility per se. However, veto power increased

happiness with outcome even after elimination of all veto trials, and the supervisors' increase in HWO ratings to the introduction of veto power also remained a slight effect, indicating that veto power has a more sustained effect on participants' happiness with the outcome of their actions.

General Discussion

The present series of experiments aimed at elucidating how sense of agency forms in hierarchical dyads. To this end, we invented a stock-exchange simulation game. Two participants, one randomly assigned the role of supervisor, the other the role of subordinate, were asked to invest virtual money into funds to increase their profit, and we manipulated potential determinants of the sense of agency in this scenario.

Our main hypotheses related to the association of sense of agency and role in various power-distributions (H1), the independent impact of action decision and action execution (H2), the association of the three theoretically related sense of agency scales of perceived causation, perceived responsibility, and happiness with outcome (H3), the impact of action outcome on all three scales (H4), the relationship of actual control on sense of agency and happiness with outcome, and the impact of a (partial) reinstatement of power via veto options (H5a), and finally the nature of the impact of veto options (sustained vs. situational; H5b).

Action decisions, action execution, and role

Our experiments extend previous findings substantially by focusing on both, the supervisors' and the subordinates' perspectives, by targeting the interplay of action decisions and action executions, and by implementing clear and sustained hierarchical roles in a benign setting (Caspar et al., 2016, 2020, 2021).

Role played a determining factor in sense of agency formation. Supervisors systematically perceived more causation and more responsibility, and, likewise, attributed causation and responsibility more to themselves than subordinates did. This pattern was consistently present in all experiments, in flat and steep hierarchical situations alike. However, hierarchical factors mediated this effect: When outcome-related degrees of freedom were equally distributed across roles, the supervisors' increase in perceived causation and perceived responsibility ratings was relatively small in absolute numbers.⁶ In steeper hierarchies with a more uneven distribution of degrees of freedom, the effect became much more pronounced (Experiments 2 and 3). Note, however, that in these circumstances, the factor role became entangled with the power to make action decisions.

Indeed, Experiments 2 and 3 studied the independent contributions of action decisions and action execution on sense of agency formation with both factors clearly contributing to sense of agency ratings. Thus, when action decision and action execution were separated between agents, sense of agency and sense of responsibility ratings were intermediate. Action decision was the most decisive factor of the two, but action execution was especially impactful for subordinates, increasing their sense of agency ratings more strongly than the supervisors'

⁶ Even in flat hierarchies, supervisors made one choice more than subordinates, namely regarding the distribution of control in this very trial (within the limits of the experiment). All decisions and actions directly related to the outcome, i.e., money and stock choice, however, were equally distributed across the experiment. Nevertheless, this first choice could have also affected the participants' evaluation of their contribution to the outcome (even though this choice did not affect outcome directly).

ratings were decreased in the same condition. Interestingly, we found a slight dissociation in causation and responsibility patterns here: When subordinates executed the action perceived causation decreased more strongly in supervisors, while perceived responsibility reduced only slightly in these situations. This hints at a more sustained and less situational conceptualization of role for perceived responsibility. Veto power further increased the impact of action executions on both, the supervisors and the subordinates' ratings.

The impact of action outcome

As expected, happiness with outcome was strongly associated with actual action outcome. The picture is less clear, however, for the association of action outcome and sense of agency and sense of responsibility.

Previous literature indicates that positive action outcomes are associated with increased sense of agency (e.g., Gentsch et al., 2015; Reis et al., 2022), and thus we expected higher sense of agency levels for positive outcomes compared to negative and neutral outcomes. Across all three experiments, however, we did not find any evidence for a substantial impact of valence of outcome on the participants' sense of agency or sense of responsibility. These findings give a first hint that the association of sense of agency and positive affect may be more complex than previously assumed. For example, social responsibility may be more pronounced for negative outcomes than for neutral (or even for positive) outcomes, because own failure extends to the co-agent and thus weighs more heavily than in single agent scenarios. This is in line with findings that agents alter their risk-taking behavior when having responsibility for a co-agent's wins or losses (Pahlke et al., 2015). That is, while it is possible that positive outcome is associated with more sense of agency in accordance with self-serving bias (e.g., Miller & Ross, 1975), control also comes with more responsibility, especially in situation in which agents are responsible not only for themselves but also for others. In relatively benign situations such as the present experiment (and as in many real-life hierarchical relationships), this social responsibility might be especially pronounced in situations of perceived failure, i.e., for negative action outcome, thus counteracting the association of sense of agency and sense of responsibility with positive outcomes. This notion fits nicely with our analyses regarding power, control, and happiness with outcome.

Power, control, and veto options

Actual control had little effect on happiness with outcome in either experiment. In Experiment 1, the actual control distribution (who makes which decision?) did not affect happiness with outcome across participants. This picture is different in Experiments 2 and 3: in unequal hierarchies with a steep power distribution, subordinates are generally happier with outcomes than supervisors. And, in fact, a reinstatement of control by veto options increases happiness with outcome by elevating the supervisors' happiness with outcome ratings. In other words, giving up control seems to have a beneficial effect on happiness with outcome. Moreover, the differences between the subordinates' and supervisors' HWO ratings are mainly found in trials with negative or neutral outcomes, and this difference is then alleviated when veto options increase the supervisors' HWO ratings. These results further support our interpretation

that power and control lead to an enhanced sense of agency and sense of responsibility that may weigh more heavily on participants, especially in situations of social responsibility, when their decisions also affect their co-agents' reward. This is mirrored in decreased happiness with outcome ratings for participants that hold more power, especially for negative or neutral action outcomes. Thus, lower HWO ratings in situations with more responsibility might reflect a more critical perspective on action outcomes based on higher expectations regarding one's own performance.

These findings expand previous discussions on control and positive affect (e.g., Bown et al., 2003; Leotti & Delgado, 2011; Leotti et al., 2010; Lorenz et al., 2015), pointing towards differences between having choices and making choices (Barnett et al., 2008; Ogden et al., 2008) and to the difference between acting alone and acting together in equal or unequal relationships (e.g., Pacherie, 2014; Pahlke et al., 2015).

Whereas our findings show, somewhat unexpectedly, that power, control, and happiness with outcome are not as clearly associated as previously assumed, our results demonstrate that sense of agency and sense of responsibility are both finely calibrated to actual power, supporting previous findings on this question (e.g., Schwarz et al., 2022; van der Weiden et al., 2011). The role per se, the distribution of control (Experiment 1), the separation of action decisions and action execution (Experiments 2 and 3), and the veto options (Experiment 3) all affect sense of agency and sense of responsibility in the predicted manner. As such, supervisors tended to have higher sense of agency and sense of responsibility ratings in all experiments, but more so, when power was unevenly distributed between supervisors and subordinates. The partial reinstatement of power by veto options for subordinates, in turn, decreased sense of agency in supervisors and increased sense of agency in subordinates.

Interestingly, although subordinates could decide to veto the supervisor's decisions on all trials in which they executed the action until they exhausted their veto options, the impact of veto power remained very situational for sense of agency and sense of responsibility ratings. That is, when veto trials were excluded, the results patterns for both ratings did not differ significantly between Experiments 2 and 3. Thus, even though subordinates had the option to veto the supervisors' decisions, their sense of agency and sense of responsibility only increased when they actually realized this option; the option alone did not affect perceived causation and perceived responsibility significantly.

Veto options, however, affected happiness with outcome ratings more sustainably: even when veto trials were excluded, HWO ratings were still higher in Experiment 3 than in Experiment 2, and especially with regards to the supervisors' ratings. Thus, the mere option for subordinates to veto the supervisors' decisions seems to have altered the supervisors' evaluation of the outcome as more positive even if that veto was not realized.

Sense of agency, sense of responsibility, and happiness with outcome

Explicit sense of agency is measured on a variety of scales including questions regarding causation and responsibility, and we utilized our experimental design to compare both rating patterns systematically with respect to a variety of situational aspects. Moreover, we investigated how sense of agency relates to happiness with outcome.

Our results mirror previous findings in that rating patterns for sense of agency and sense of responsibility are highly similar across participants (Reis et al., 2022). However, a few slight discrepancies in specific situations indicate that, while conceptualizations of both might be strongly co-dependent, they are probably not identical. Perceived responsibility remained relatively high even when subordinates executed the action, whereas perceived causation decreased more strongly in these situations. Only when power (and control) was partially reinstated in subordinates via veto options, did perceived responsibility decrease similarly to perceived causation. This might indicate that perceived responsibility is more closely associated with a sense of power and thus less easily affected by situational differences.

Previous studies suggest that increased sense of agency should be perceived as rewarding and is associated with positive affect (Bown et al., 2003; Leotti & Delgado, 2011; Leotti et al., 2010; Lorenz et al., 2015, but see Reis et al., in revision). This would imply that participants might also be happier with the outcome if they perceive more sense of agency for an action. This, however, is not the case in the present experiment. Happiness with outcome was largely unrelated to both sense of agency and sense of responsibility ($r_s < .12$). To the contrary, subordinates were generally happier with the action outcome in unequal hierarchies, especially when they did not contribute to action decisions. Although happiness with outcome increased due to the introduction of veto power, this effect was not due to an increase of HWO ratings in subordinates, but instead an increase of HWO ratings in supervisors. In addition to social factors inducing pressure to succeed and thus limiting the participants' HWO, a further possible explanation could be that in most studies on sense of agency, action outcome is somewhat predictable (see, e.g., Schwarz et al., 2022, for a recent comparison of predictability and perceived control). In the present series of experiments, however, investment outcome was largely unpredictable, although participants could infer on future outcomes based on experience with previous investments (see the subsection *The Influence of Learning*). Thus, actions in this study could at least partly lack the satisfying and rewarding experience of an accurate prediction or an expectation coming true which is present in most studies investigating the rewarding aspects of control and could thus account for some of the differences found in previous studies and our series of experiments. However, the positive mean outcome throughout the experiments suggests that participants generally very early on understood how to produce positive results in the present experiments, even though singular trials could still result in unexpected outcomes.

The Influence of Learning

As participants were able (and did) learn how to produce positive results throughout the experiments, we tested whether these effects could have viable influence on the participants' perceived causation, perceived responsibility, and happiness with outcome. Interestingly, we found no learning effects for Experiments 1 and 2; indeed, participants were so quick to learn how to produce positive outcome that outcomes did not differ between various stages of the experiment. The influence of learning on the participants' rating pattern should thus be negligible for the first two experiments.

Experiment 3 showed different results, however, potentially due to a smaller number of trials that were adjusted to comply with time restrictions because of COVID19-related safety procedures. Although participants showed positive outcome in all stages of the experiment, they

also showed learning effects with improved outcome towards later stages of the experiment compared to earlier stages. Indeed, outcome in the later stages of the experiment proved similar to Experiment 2 throughout, indicating that the outcomes at later stages of Experiment 3 rely on similar learning success as the outcomes of Experiment 2. Moreover, we found that this learning process was also reflected in the participants' rating patterns: The participants' perceived causation and responsibility changed over time, differently for supervisors and subordinates, with supervisors perceiving more causation and responsibility, and subordinates less. Moreover, both, supervisors and subordinates, reported more happiness with outcome over time. When we included the data of Experiment 2 into the analysis, the results indicated that learning effects indeed do underlie the differences in perceived causation and perceived responsibility over time, as these rating differences are present in Experiment 3, but not in Experiment 2. However, the changes of happiness with outcome over time did not differ between experiments, suggesting that the increase in happiness with outcome might be genuine order effect not primarily reliant on learning processes.

As previous work indicates that predictability is indeed a critical factor in sense of agency formation (e.g., Schwarz et al., 2022), the impact of learning (and thus predictability of outcome) on sense of agency in Experiment 3 is not surprising. However, we did not predict the differential effect dependent on role; the more subordinates seem to understand how the system can be "worked" to derive better results, the less causation and responsibility they perceive. This does not reduce their enjoyment, however, as both, supervisors and subordinates show increased happiness with outcome over time.

Limitations and Future Directions

The present series of experiments intended to evaluate and characterize sense of agency, sense of responsibility, and happiness with outcome in hierarchical settings. We believe that our experimental approach is characteristic of many benign interactions in real-life, e.g., supervisor-subordinate relationships in many companies or universities, teacher-student or parent-child relationships, etc.⁷ However, matters might be different for less benign interactions, including, for example, pressure to perform (e.g., due to potential punishments in case of poor performance), strongly competitive relationships between agents, unfair conditions, morally questionable behavior, or even mere enmity between agents. As these circumstances may be more (negatively) emotionally charged, especially our findings with regards to happiness with outcome and social responsibility may show different result patterns in these scenarios. For example, previous research suggests that outcome distribution affects the participants' sense of agency in general, and the influence of role on the participants' sense of agency in particular. Sense of agency was generally high in situations of equal distribution, especially for joint agency ratings, and was otherwise higher when participants received part (or all) of the outcome gains

⁷ Please note that we do not want to claim that these relationships are all similar in other aspects as well, but simply, that they all include hierarchical relationship that are, in most cases, of benign or at least neutral nature.

(in equal, fair and unfair conditions) compared to situations in which they, unfairly, gained nothing at all. Moreover, differences in sense of agency between roles were most pronounced when outcome was differentially, but fairly distributed (i.e., in accordance with actual action contribution) suggesting a fine-grained association of sense of agency and fairness perception in human agents (LeBars et al., 2020). Finally, more competitive situations seem to instill more selfish action choices in individuals in power as well as affect participants' perceived control compared to more benign settings, thus indicating that the general atmosphere of a joint action setting might play an influential role in how sense of agency emerges (LeBars et al., 2022).

Moreover, role was randomly assigned in our experiment. However, in real-life situations, role is more organically derived, e.g., by a sustained status of an agent. As such, agents that have deliberately chosen and worked for their role as supervisors might be more inclined to embrace the burden of responsibility also for their co-agents' gains and losses, than a participant coincidentally taking over this role. Moreover, individuals in higher positions are ideally chosen due to their knowledge and competence, possibly inducing feelings of trust in their subordinates and in themselves, affecting their choices as well as their reactions to those choices' consequences. Nevertheless, this difference in role selection does not necessarily mean that these agents are not similarly affected by the situational factors investigated in this series of experiments; the effects might simply be mediated by those personality traits that have facilitated the agents' rise in status.

We also did not investigate individual factors that might have played a role in decision-making processes, such as risk preferences. Indeed, such factors could interact with the given roles, in that specific roles might invite more risk-taking than others (Maner et al., 2007). For example, due to a perceived lack of responsibility, subordinates might be more inclined to make risky decisions. It is possible that such role-specific processes may underlie some of the current results; future studies could further characterize which reasons may lie behind the differential response patterns of subordinates and supervisors.

When designing the present stock exchange paradigm, we took care to maintain meaningful connections to traditional laboratory paradigms in which participants choose between different action choices rather than a situation even closer to realistic stock trading in which participants additionally may choose when to start and stop investment. Such an addition would include even more complexity to a novel (and already relatively complex) paradigm and introduce highly individual factors such as resilience to time-sensitive tasks and stressful situations which could compromise data interpretation. However, time-sensitivity is a factor in many high-risk environments so that, building on the current results, future studies might look into the question of how temporal, time-sensitive decision making might alter sense of agency and sense of responsibility accounts of both supervisors and subordinates.

Finally, we deliberately chose to focus on explicit sense of agency ratings in this series of experiments in the experimental procedure as well as for data interpretation; for one, because we wanted to analyze different rating scales that are either used synonymously in experiments or associated in theory, and for another, because implicit measures of sense of agency are currently very controversially discussed in their association with sense of agency (e.g., Hoerl et al., 2020; Klaffehn et al., 2021; Schwarz et al., 2018b, 2019; Schwarz & Weller, 2022; Siebertz et al., 2022; Tonn et al., 2021). Nevertheless, explicit ratings automatically invite potential

biases. Although the differing responses to the various situational components in our series of experiments indicate that participants responded honestly, we cannot preclude that such biases may have affected the current results. Despite all their shortcomings, we maintain, however, that explicit ratings are currently the most direct and uncontroversial measure to investigate sense of agency. We further believe that the analysis of these differing rating scales enhances our current understanding of the conceptualization underlying sense of agency, sense of responsibility, and happiness with outcome in agents.

Conclusions

This series of experiments studied how sense of agency forms in social hierarchies. Role, action decisions, and action execution contribute to sense of agency. More power was associated with more sense of agency, and actual control was mirrored in sense of agency ratings. Likewise, reinstatement of control through veto options in subordinates altered sense of agency patterns in subordinates and supervisors; however, this impact was limited to the situations in which subordinates chose to veto the supervisor's decisions, and did not extend to the situation at large. Outcome valence did not affect sense of agency in the present experiments, but had a strong impact on happiness with outcome which in turn was largely unaffected by sense of agency or actual control. Surprisingly, however, subordinates tended to be happier with outcome than supervisors, especially in situations in which they did not wield control. Similarly, supervisors became happier with outcome when control was given back to subordinates via veto options, even in situations in which subordinates did not choose to utilize their veto option. These results hint at a surprising difference between acting alone and acting with a co-agent, with a potential negative effect of social responsibility on happiness with outcome.

Constraints on Generality

Participants in the present experiments were recruited from the general, adult population (age range 18-67) and all participants identified as either male or female. Moreover, all experiments were conducted in Germany. Thus, results cannot be necessarily generalized to children and may differ in other cultures.

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