

Action co-representation under threat: A Social Simon study

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Highlight

- Action co-representation has never been studied in threat context
- Social buffering took place in presence of co-partners
- Co-representation is maintained under threat contexts
- Co-representation may be boosted under threat near safe partners
- Being under threat appears to promote affiliative and social behaviors

Abstract

Several studies have shown that individuals automatically integrate the actions of other individuals into their own action plans, thus facilitating action coordination. What happens to this mechanism in situations of danger? This capacity could either be reduced, in order to allocate more cognitive resources for individualistic actions, or be maintained or enhanced to enable cooperation under threat. In order to determine the impact of the perception of danger on this capacity, two groups of participants carried out, in pairs, the Social Simon task, which provides a measure of co-representation. The task was performed during so-called ‘threat blocks’ (during which participants could be exposed at any time to an aversive stimulus) and so-called ‘safety blocks’ (during which no aversive stimulation could occur). In a first group of participants, both individuals were exposed at the same time to threat blocks. In a second group, only one of the two participants was exposed to them at a time. Our results indicate that co-representation, an important cognitive mechanism for cooperation, (i) is preserved in situations of danger; and (ii) may even be increased in participants who are confronted alone to threat but in the presence of a safe partner. Contrarily to popular belief, danger does not shut down our capacities for social interaction.

Introduction

Dangers are integral part of our lives. Humans are social animals and have evolved a series of individual adaptations and collective decision rules to cope with a wide variety of threats, such as disease transmission (Neuberg, Kenrick, & Schaller, 2011; Tybur & Lieberman, 2016), predatory encounters (Caro, 2005) and natural disasters or ecological shocks (Drury & Reicher, 2010; Henrich, 2017). Danger is so much part of our lives that our social inclinations have been suggested to have evolved in response to predatory pressures, with increasing group size being an adaptation to alleviate the costs of vigilance (Lima, 1995; Roberts, 1996), allowing for threat dilution and the preparation of collective responses (Caro, 2005). How are those collective responses to danger even possible in humans? Which are the cognitive mechanisms that allow us to coordinate with others in the face of danger?

One really persistent belief about human reaction under threat is that our own responses to danger are fundamentally asocial and/or antisocial (Dezecache, 2015). When threatened, humans run for their lives, and may even trample others to access safety (Le Bon, 1895; Quarantelli, 2001). In fact, those apparently asocial reactions could be inherently social, and flight possibly a strategy to approach familiar conspecifics and places (Mawson, 2005). What's more, humans engage in coordinated actions even when directly exposed to a deadly danger, and in perfect knowledge of the risk. In a study we led on survivors' reactions during Paris terrorist attack (Dezecache et al., 2020), we found leg-up to climb up to exits, votes to decide on the next decisions to be taken and many other coordinated responses to maintain individual and collective safety. These results are consistent with previous studies on the evacuation of the World Trade Center (Fahy & Proulx, 2005) or the London bombing attacks (Drury, Cocking, & Reicher, 2009) which report risk taking to help strangers and a sense of unity between survivors, suggesting that our social cognitive capabilities are at work during intensely stressful situations.

Over the last decade, several behavioral and neuroimaging experiments have investigated the impact of threat (acute stress) on social behaviors, such as the processing of non-verbal social cues (Kavcioglu, Bublatzky, Pittig, & Alpers, 2019; von Dawans, Spenthof, Zimmer, & Domes, 2020), affiliative (Berger, Heinrichs, von Dawans, Way, & Chen, 2016; Coan et al., 2017) and empathic tendencies (Tomova et al., 2017) as well as social decision-making (Nickels, Kubicki, & Maestripieri, 2017; von Dawans, Ditzen, Trueg, Fischbacher, & Heinrichs, 2019; von Dawans, Fischbacher, Kirschbaum, Fehr, & Heinrichs, 2012). These experiments (e.g. Margittai et al., 2015; Tomova, Saxe, Klöbl, Lanzenberger, & Lamm, 2020;

von Dawans et al., 2019; Von Dawans et al., 2012) clearly indicate that anticipated or experienced threats can promote affiliative and social behaviors, in agreement with the “tend-and-befriend” hypothesis (Taylor, 2006). Furthermore, these past studies, which almost exclusively examined elements of social cognition in socially isolated participants, provide methodological tools to pursue the investigation of the cognitive consequences of being afraid in social settings.

Many of behavioral strategies under threat observed in animal kingdom are performed in group, and reactions to perceived danger consist of a set of behaviors that cascade. When a threat is detected, social information acquisition processes are put in place, whereby detectors voluntarily or involuntarily inform other individuals of the presence of the danger (Caro, 2005). Once information is passed on to conspecifics, strategies for responding to danger develop. In the animal, these strategies include solo and social flight, concealment, social contact seeking and coordinated attacks on the predator (Caro, 2005). It is perfectly reasonable to assume that the human cognitive system (as a product of biological evolution) has also been shaped to collectively respond to danger. Consequently, there is a need to conduct (i) studies under threat in the presence of others, (ii) targeting cognitive functions involved in setting up and taking part in collective actions.

In threat-free situations, successful joint actions (such as moving furniture) are already complex tasks. Agents need to anticipate others’ actions, integrate their own action representations with those of others, to then be able to spatially and temporally coordinate their own action with those of others (Era, Candidi, Gandolfo, Sacheli, & Aglioti, 2018; Knoblich & Sebanz, 2006). Efficient coordination relies on a complex set of cognitive mechanisms (Constable, Pratt, Gozli, & Welsh, 2015; Obhi & Sebanz, 2011; Sebanz & Knoblich, 2009), such as visual and conceptual perspective taking (i.e. abilities to represent others’ visual and reasoning point of view) or action and goals co-representation (i.e. abilities to represent others’ action plans and intention). It is now established that humans tend to represent the visual (Fini, Committeri, Müller, Deschrijver, & Brass, 2015; Gobel, Tufft, & Richardson, 2018) and motor-perspective of people (or agents showing biological movement) they act with (Atmaca, Sebanz, & Knoblich, 2011; Müller, Brass, et al., 2011; Sahaï, Desantis, Grynszpan, Pacherie, & Berberian, 2019; Stenzel et al., 2012, 2014; Tsai, Kuo, Hung, & Tzeng, 2008). This propensity to co-represent others is associated with affiliative tendencies towards co-actors (Bukowski & Samson, 2016).

What should happen in threatening situations? Although associated with affiliative tendencies, co-representation may well be reduced in contexts where it can incur costs to the agent, such as in joint tasks in which the contribution of each co-agent is independent and clearly distributed (Tufft & Richardson, 2019). Co-representation could even be shut down, such as when participants are co-acting in competitive contexts (Iani, Anelli, Nicoletti, Arcuri, & Rubichi, 2011), confronted to hostile conspecifics (Hommel, Colzato, & Van Den Wildenberg, 2009), or under the experience of negative affective states such as sadness, anger and/or anxiety (Kuhbandner, Pekrun, & Maier, 2010; Todd, Forstmann, Burgmer, Brooks, & Galinsky, 2015; Todd, Simpson, & Cameron, 2019; Todd & Simpson, 2016). These findings suggest that co-representation mechanisms may be tuned to allow for collaborative activity only when necessary, adjusting the amount of cognitive resources devoted to own vs. others' actions (Mendl, Fröber, & Dolk, 2018). As co-representing others' actions can be costly and thus can diminish the possibility to allocate resources to one's own asocial behaviors, it may be reduced or even interrupted under threatening situations.

On the other hand, as threat situations are inherently social situations (where others are both to be protected and to act with), it may well be that co-representation is maintained or boosted to promote social strategies that survivors described as essential for their own survival. Coherently, co-representation is known to be susceptible to the presence of social indices and favored toward in-group and friendly individuals as well as under cooperative contexts (Aquino et al., 2015; Iani, Anelli, Nicoletti, & Rubichi, 2014; McClung, Jentsch, & Reicher, 2013; Müller, Kühn, et al., 2011). Such increases in co-representation can possibly be explained by the interdependence between co-agents (i.e., others represent an advantage or an obstacle to reach personal goals, Era, Aglioti, et al., 2018; Iani et al., 2014; Ruys & Aarts, 2010), which modulates the willingness to invest in an interaction (Poortvliet & Darnon, 2010). So far, evidence leads toward contradictory predictions. Since co-representation has never been studied in threat contexts, the question remains as to whether it is impacted under threat.

Here, we used the Social Simon task, suggested to measure self-other integration (Sebanz, Knoblich, & Prinz, 2003; Sebanz, Knoblich, Prinz, & Wascher, 2006, for review see Dolk et al., 2014, for meta-analysis Karlinsky, Lohse, & Lam, 2017), to investigate the cognitive processes underlying joint actions in humans under moderate threat. In the standard Simon task (Hommel, 2011; Simon & Rudell, 1967), a single participant categorize binary non-spatial stimuli (e.g., violet and grey cues) randomly presented to the left or right side of the

screen. Participants use two spatially defined keypresses, such as the left and right “Ctrl” keypresses, each of them being associated with one stimulus (e.g. left-violet & right-grey). Even though stimulus location on the screen is completely task-irrelevant, participants are slower to respond when the cue is not spatially aligned with the corresponding keypress (incongruent trials) as compared to when it is aligned (congruent trials). This difference in reaction times, called the Simon Effect (SE), rests upon the fact that, during incongruent trials, spatial and non-spatial information activate two different action plans that compete with each other, thus slowing down participant’s responses to the cue. Hence, when the same participant performs a go/no-go version of the task, i.e. being responsible for only one keypress (e.g. only left-violet), the SE disappears. However, and of interest here, when the same go/no-go version of the task is performed with a conspecific seated next to the participant, such that each of them is responsible for one keypress, the SE re-appears in both members of the dyad. This alter-centric interference, better known as Social SE, may be regarded as an measure of self–other integration, typically explained by an automatic co-representation of surrounding individuals’ actions (Sebanz et al., 2003 but see Dolk, Hommel, Prinz, & Liepelt, 2013 for contention on the underlying mechanisms).

In the present work, dyads of participants performed the Social Simon task under a “threat-of-scream” procedure (Patel, Stoodley, Pine, Grillon, & Ernst, 2017; Patel et al., 2016). This procedure consists in alternating time-periods in which participants are at risk of hearing unpredictable aversive distress screams (threat blocks) with time-periods in which no such screams are to be delivered (safe block). Using this procedure, we previously revealed that unpredictable threats (distress screams) generate sustained aversive states in participants, reflected by higher subjective reports of anxiety, higher skin conductance level, and positive correlation between the two measures, in threat compared to safe time periods (Beaurenaut, Tokarski, Dezechache, & Grèzes, 2020). Here, we tested the hypothesis that the alter-centric interference (Social SE) is affected during threat blocks. If our hypothesis is correct, we will better understand how social cognitive capabilities that allow us to coordinate and plan actions with others are engaged during threatening situations. If primary reactions to danger are asocial/anti-social, we should observe a decrease in co-representation, i.e., of the Social SE in threat compared to safe time periods. However, if in agreement with previous experiments on anticipated or experienced threats (e.g. Margittai et al., 2015; Tomova et al., 2020; von Dawans et al., 2019; Von Dawans et al., 2012), primary reactions to danger are social and affiliative, action co-representation should be maintained or enhanced, i.e., we

should respectively observe no change or an increase of Social SE in threat compared to safe time periods.

Finally, to explore the situational determinants behind potential changes in action co-representation under threat, we created two versions of the Social Simon Task. In the Common fate version, the members of a dyad were simultaneously exposed to distress screams during threat blocks, and were simultaneously safe during safe blocks. In the Non-Common fate version, and for each block, only one member of the dyad at a time was exposed to distress screams, while the other was safe (and the reverse in the next block). On the one hand, the perception of a common fate can cause the adoption of a common social identity (Drury et al. 2009) and the Social SE was shown to be influenced by perceived interpersonal similarity between co-agents (e.g. Müller, Brass, et al., 2011; Müller, Kühn, van Baaren, et al., 2011– Pinocchio and group members). Within this perspective, the magnitude of the Social SE should be greater in the Common version compared to the Non-Common one. On the other hand, affiliative tendencies were suggested to depend on the perceived or anticipated benefit and damage of being with another to one's own ability to cope with the current anxiety-inducing context (Rofé, 1984). Individuals not only spontaneously track their partner's abilities and/or resources to act (Doerrfeld, Sebanz, & Shiffrar, 2012; Low, Edwards, & Butterfill, 2020) but also seek out affiliation from more fortunate (upward contacts) rather than less fortunate others (Taylor & Lobel, 1989). Within this perspective, the magnitude of the Social SE should be increased in threatened compared to safe members of the dyad in Non-Common fate (see Dezechache, Grèzes, & Dahl, 2017).

Methods

Insert Figure 1 – Protocol – Here

Participants

Seventy-eight healthy volunteers (38 females; mean age 23.5 ± 4.3 years SD) were recruited to participate in the study. All participants were right-handed, had normal or corrected-to-normal vision, and had no history of neurological or psychiatric disorders. The experimental protocol was approved by INSERM and the local research ethics committee (Comité de protection des personnes Ile de France III - Project CO7-28, N° Eudract: 207-A01125-48), and it was carried out in accordance with the Declaration of Helsinki. The participants provided informed written consent and were compensated for their participation.

Twenty dyads of same gender (10 dyads of females, of mean age 23.4 ± 4.3 years SD) were randomly assigned to Common group, while nineteen dyads (9 dyads of females, of mean age 23.6 ± 4.5 years SD) were assigned to the Non-Common group. Participants did not know each other, and were not allowed to talk to each other until the end of the experiment.

General Procedure

First, participants were recruited thanks to an online advert, which consisted of a short description of the study and included an internet link which directed participants to a Qualtrics survey. Due to the potentially stressful nature of our paradigm and after discussion with the referent medical doctors of our laboratory, we requested participants to fill in, online and anonymously, the French versions of State-Trait Anxiety Inventory Spielberger (STAI, Spielberger, 1983) and Post-traumatic stress disorder Checklist Scale (PCLS, Weathers, Litz, Herman, Huska, & Keane, 1993), at least one week before the experiment. Only participants with a score below 40 for the PCLS and below 60 for both STAI state and trait anxiety were included in the experiment.

Second, two days before the experimental session, participants that were included in the experiment filled in online the Liebowitz Social Anxiety Scale (LSAS, Heimberg et al., 1999) and the Trait-STAI questionnaire. On that occasion, an anonymous code was attributed to each participant, and use for both the questionnaires and the behavioral data. Moreover, on the day of the experiment, upon arrival at the lab, the two participants completed on a computer, in two different rooms, the State-STAI questionnaire. This allowed to ensure that their state level of anxiety was in the “normal” range (below 60) before the experimental session that

aimed at manipulating their anxiety. LSAS and STAI distribution for each group are provided in Supplementary Material (see **Figure S2**) and didn't differ between groups (all p s > 0.28, see **Tables S35 - S41**).

Third, after providing the instructions regarding the main task, the experimenter placed the skin conductance electrodes. To identify potential physiological non-responders before the main experiment, the experimenter assessed the variation of the physiological signal while participants were asked to imagine a situation during which they fell into really cold water, and this, until stopped by the experimenter. All our participants showed increased physiological response during this mental imagery task; the response then dropped when asked to stop the exercise. Based on this definition of 'non-responder', there were no non-responders among our participants.

Fourth, participants started with a 3-minute training session, before performing the main experiment for approximately 30 minutes, and were carefully debriefed at the end of the main experiment. During the debriefing, participants were notably requested to rate how aversive the screams were for them and how much they felt preoccupied by the possibility that a scream would be delivered during threat blocks (from 0 - not at all to 10 - extremely).

Experimental design and task (Figure 1)

The experiment consisted in a modified version of the Social Simon task (Sebanz et al., 2003) (**Figure 1A**), performed by dyads of participants during alternating blocks of threat-of-screams or safety. Participants were either assigned to the Common or the Non-Common group. Dyads of participants in the Common group systematically shared the same experimental context: both participants performed the task during blocks before which they were told that they could hear aversive screams at any time (threat blocks) vs. blocks before which they were told that no scream will be heard (safe blocks). Participants were informed that during threat blocks, the color bands located on both sides of the screen will be blue, and that, at any time during the block, unpredictable distress screams could be delivered through their headphones. In contrast, they were informed that during safe blocks, both sides of the screen were to be green, meaning that no screams were to be delivered. The nature of the first block was counterbalanced across dyads of participants.

Contrary to the Common group, dyads of participants in the Non-Common group never shared the same experimental context: participants were informed that when the color band located on their side of the screen was blue, the color band located on the side of the other

participant was to be green, meaning that only them were at risk to hear unpredictable distress scream through their headphones (i.e., they were alone in a threat block), whereas the other participant was completely safe. Safe and threat conditions were reversed at the end of each block.

The temporal organization of each block was as follow (**Figure 1B**): a black screen with the written instruction “stabilization of the signal” was first presented for 1 minute during which the physiological baseline of participants was recorded. Second, to inform participants from the Common group about the nature of the block, the written instruction “Threat Block: at any time, a scream can be presented to both of you at the same time” or “Safe Block: Both of you will hear nothing during this block” was presented for 10 seconds. For the Non-Common Group, the written instruction “Participant X - Threat Block: at any time, a scream can be presented to you and only you” and “Participant Y - Safe Block: You and only will hear nothing during this block” was presented for 10 seconds. Third, participants performed the Social Simon task for about 4 minutes. Fourth, at the end of each block, participant reported one by one their anxiety level on a continuous scale (from 0: really calm to 100: really anxious), by moving a cursor on the screen using the mouse. One after another (and in random order), participants were asked to close their eyes and turn their head to allow their co-participant to respond anonymously. Note that since participants wore sensors, they could not exit the room temporarily. The written instruction “Participant X – Turn your head and close your eyes” and “Participant Y – please press start to display the scale” were presented. The scale was presented on the computer screen and disappeared once the response was given. As participants were not allowed to talk, a short bell sound indicated to them they were allowed to look back at the screen”. Finally, to assess physiological variation of participants’ bodily state in threat compared to safe blocks, skin conductance activity was recorded throughout blocks for each participant.

The temporal organization of each trial was as follow (**Figure 1C**): at the center of the screen, a rectangle surrounding three horizontally arranged empty circles first appeared for 500ms, after which one of the circles became either violet or grey for 150ms. The colored cue could appear on 3 different locations: on the center circle (10% of the time), on the left one (45% of the time) or on the right one (45% of the time). Each color cue was associated with a button (e.g. violet – “Ctrl Left” or grey – “Enter Right”), and each participant of the dyad was responsible for one key-color cue association. The key-color cue associations were randomized between participants. Participants were requested to respond as soon as they saw

the color cue corresponding to their key-press by using their right index finger, regardless of the color cue's position. After participant responded, an interval of 1000ms was included before the start of the next trial.

A training session was performed before the main experiment to familiarize participants with the Social Simon Task, the structure of the experiment (the alternation of safe and threat blocks and their associated screen side colors) and the screams. Participants were trained on 2 blocks, one safe and one threat, each of 32 trials. During the threat block, 2 distress screams (from one male and one female) were delivered once during two randomly chosen trials from among the 32 possible trials (approximately 6% of the trials). Note that the two screams used for the training were different from the 6 screams used during the main experiment.

Participants then performed the main experiment, divided into 4 blocks of 90 trials, 2 threat blocks and 2 safe blocks. During each threat block, 6 distress screams were delivered once, randomly during the block (approximately 6% of the trials), either at the beginning of the trial (2 screams), before the color cue appeared (2 screams), or when it disappeared (2 screams).

Screams stimuli

The screams were provided by Professor Armony, and had been previously validated (Fecteau, Armony, Joanette, & Belin, 2005) by 60 participants who rated the stimuli on emotional valence and intensity. From the 12 screams in Fecteau and colleagues' study, we selected eight for the present protocol (4 from males and 4 from females). These eight screams were normalized at -2b using audiosculpt 3.4.5 (<http://forumnet.ircam.fr/shop/fr/forumnet/10-audiosculpt.html>). During both the training session and the main experiment, screams were delivered using two Bose headphones (QuietComfort 25) at peak intensity below 70 dB (mean of 68 dB as measured by a sonometer). The screams effectiveness in inducing anxiety was previously validated in the experimental set up developed by Beaurenaut et al. (2020). Furthermore, the participants recruited in the present study rated them as moderately aversive (median of 4 on a scale from 0 to 10) and reported being relatively preoccupied by the possibility that a scream would be delivered during threat blocks, (i.e. they reported anticipatory anxiety of scream delivery, median of 5 on a scale from 0 to 10).

Skin conductance recordings

Skin conductance activity was recorded using a PowerLab 8/35 amplifier, with two GSR Amp (FE116) unit which uses low, constant-voltage AC excitation (22 mV rms at 75 Hz), and two

pair of stainless steel dry bipolar electrodes (3x2,5cm, MLT118F). The electrodes were attached to the participant's left index and ring fingers of the non-dominant hand, using dedicated Velcro. Recordings were performed with LabChart 7 software, at a sampling rate of 1 kHz, with the recording range set to 40 μ S and using initial baseline correction (“subject zeroing”) to subtract the participant's absolute level of electrodermal activity from all recordings (devices and software from ADInstruments). Finally, as low-pass filter of 0.05Hz has been proposed as an appropriate filter to eliminate any noise as well as the phasic component of the signal (see Braithwaite et al., 2013), we applied it to isolate the tonic activity of the skin conductance signal and to minimize the phasic influence of screams during threat blocks on the skin conductance activity (see Beaudenaut et al., 2020).

Skin conductance level (SCL) processing

The SCL corresponds to the tonic activity of the skin conductance signal. The physiological signal was processed using Labchart 7 and Matlab. For each participant and for each block, we obtained (a) one SCL value corresponding to the averaged signal over the 1-minute baseline at the start of the block (see **Figure 1B**), and (b) one SCL value corresponding to the averaged signal over task performance. The instruction phase (Condition + Readyng - see **Figure 1B**), between 1-minute baseline and the beginning of the free action-task was not included in the averaged signal. Moreover, for threat blocks only, the phasic activity induced by the distress screams (~6% of threat block trials) was excluded from the averaged signal. Finally, for each block (whether safe or threat), variation from the baseline was obtained by subtracting the baseline activity from the averaged activity over task performance. We therefore obtained, for each participant, 2 values corresponding to the 2 Safe blocks, and 2 values corresponding to the 2 Threat blocks.

Statistical analyses

All statistical analyses were carried out using JASP Software (JASP Team (2017), JASP (Version 0.8.5.1)). The corresponding tables of results are available in Supplementary materials.

First, we checked that the threat-of-scream procedure was efficient and had similar impact on both Common and Non-Common groups. To do so, we ran two-way repeated-measures ANOVAs with Condition (Threat vs. Safe) and Time (block 1 to 2) as within-subjects factors and with Group (Common vs. Non-Common) as between-subjects factor on SCL and subjective reports of anxiety as well as t-tests on the debriefing scores of Aversiveness and

Preoccupation. Moreover, in an exploratory analysis, we assessed whether the anxiety manipulation could have been impacted when participants were in dyads rather than alone (Classical Simon task performed by 38 participants during alternating threat and safe blocks, **see Supplementary Materials in Appendix Section**). To do so, we ran repeated-measures ANOVAs with Condition (Threat vs. Safe) as within-subjects factor and with Group (Alone vs. Common vs. Non-Common) as between-subjects factor on SCL, subjective reports of anxiety, scores of Aversiveness and Preoccupation.

Second, to determine whether and how sustained anxiety impacted the Social Simon Effect (Social SE), we analyzed reaction times (RTs). An individual- and condition-specific outlier procedure was used in which RTs exceeding ± 2.5 SDs (Dolk et al., 2013; Klempova & Liepelt, 2016; Welsh, 2009) from the mean RT for that condition for that person were eliminated (2.83 % of trials). In addition, participants with an error rate higher than 10% were excluded for RT analyses (Müller, Brass, et al., 2011). The Social SE is operationalized as the difference of reaction times between trials where the position of the cue on the screen was spatially incongruent with the location of the button press (e.g., grey cue on the left) and trials where the position of the cue on the screen was spatially congruent with the location of the button press (e.g., grey cue on the right). We ran two-way repeated-measures ANOVA with Condition (Threat vs. Safe) and Congruency (Incongruent vs. Congruent) as within-subjects factors and with Group (Common vs. Non-Common) as between-subjects factor on RTs. To assess whether the Social SE was induced under Threat and Safe contexts, a t-test against zero was conducted for each condition. Effect sizes (eta-squared, η^2 or Cohen's d) are reported together with F, t and p values. As the electrodes of one participant got unplugged during two blocks and one participant had an error rate superior of 10%, both participants were excluded from the analyses (final n = 76)

Results

Quality check of the threat-of-scream procedure

Participants' tonic skin conductance activity (SCL) was greater during Threat relative to Safe blocks ($F(1,74) = 14.08, p < 0.001, \eta^2_p = 0.16$) (**Figure 2**). We observed a main effect of Time ($F(1,74) = 42.35, p < 0.001, \eta^2_p = 0.36$), suggesting a decrease of SCL in the course of the experiment. However, there was no significant interaction between Condition and Time ($F(1,74) = 0.79, p = 0.38, \eta^2_p = 0.011$), suggesting that the difference in SCL between Safe and Threat blocks did not change with time. No significant interaction with Group was observed, suggesting that SCL activity was similar between Common and Non-Common Groups (all $ps > 0.21$).

Regarding subjective anxiety, participants reported higher levels of the anxiety at the end of Threat compared to Safe blocks ($F(1,74) = 37.79, p < 0.001, \eta^2_p = 0.34$) (**Figure 2**). There was a significant main effect of Time, suggesting that participants' subjective reports decreased in intensity throughout the experiment ($F(1,74) = 5.88, p = 0.018, \eta^2_p = 0.074$). However, there was no significant interaction between Condition and Time on subjective reports ($F(1,74) = 0.009, p = 0.92, \eta^2_p \sim 0$), suggesting that the difference in subjective reports of anxiety between Safe and Threat blocks did not change with time. Moreover, no significant interaction with Group was observed, suggesting subjective reports of anxiety were similar between Common and Non-Common Groups (all $ps > 0.13$).

Insert Figure 2 – Anxiety Results – Here

In addition, the scores reported at the end of the experimental session regarding the Aversiveness of screams ($t(74) = 0.22, p = 0.83, \text{Cohen's } d = 0.051$) and Preoccupation related to screams delivery ($t(74) = -0.84, p = 0.41, \text{Cohen's } d = -0.19$) didn't differ between Common and Non-Common Groups.

Finally, in an exploratory analysis, we assessed whether our anxiety manipulation could have been impacted when participants were in dyads rather than alone (Classical Simon task performed by 38 participants during alternating threat and safe blocks, see Supplementary Materials). The ANOVAs revealed a significant Group by Condition interaction for the SCL ($F(2,111) = 3.66, p = 0.03, \eta^2_p = 0.062$), the Subjective anxiety ($F(2,111) = 7.38, p < 0.001, \eta^2_p = 0.12$) and the Preoccupation score ($F(2,111) = 4.72, p = 0.011, \eta^2_p = 0.078$) suggesting that overall, the induction of sustained anxiety was stronger when participants performed the task alone (see **Tables S21 – S31**) than when performing the task in dyads.

Social Simon Effect

Neither the main effect of Condition ($F(1,74) = 0.71, p = 0.40, \eta^2 = 0.010$), nor the interactions between Condition and Group ($F(1,74) = 0.91, p = 0.34, \eta^2 = 0.012$), or between Condition and Congruency ($F(1,74) = 0.64, p = 0.43, \eta^2 = 0.009$), or between Congruency and Group ($F(1,74) = 0.066, p = 0.80, \eta^2 = 0.001$) on RTs were found significant. The main effect of Congruency on RTs, which reflected the classical Social SE, was found to be significant ($F(1,74) = 48.52, p < 0.001, \eta^2 = 0.40$). Participant were slower during incongruent compared to congruent trials. T-tests against zero show that the Social SE was present and significant in both Safe and Threat blocks and in both Common and Non-Common groups (all $ps < 0.01$, Cohen's $d > 0.47$, see **Tables S8 and S11**).

Moreover, we observed a small but significant triple interaction between Condition, Group and Congruency ($F(1,74) = 5.55, p = 0.021, \eta^2 = 0.070$). To better understand this interaction, we fitted separated ANOVAs on Common and Non-Common groups respectively (**Figure 3**). In the Common group, i.e. the two members of the dyad were exposed to the same experimental context, the interaction between Congruency and Condition was not significant ($F(1,39) = 1.32, p = 0.26, \eta^2 = 0.033$), suggesting that the Social SE was of similar size during Safe and Threat blocks. In contrast, in the Non-Common group, i.e. the two members of the dyad were never exposed to the same experimental context, the interaction between Congruency and Condition was significant ($F(1,35) = 4.57, p = 0.040, \eta^2 = 0.12$), suggesting that the Social SE was increased when participants were exposed to an aversive situation on their own while their partner was safe.

To complement the traditional frequentist statistical analyses (**Figure 4**), we performed Bayesian t-tests to quantify the relative strength of our empirical data in favor of (i) a Social SE in both Safe and Threat Contexts, (ii) a differential impact of Condition on Social SE as a function of the Group Fate. First, Bayesian t-test against zero on the Social SE in Safe and Threat revealed a strong level of evidence in favor of the existence of a Social SE in both Safe (Bayes Factor = 6330) and Threat blocks (Bayes Factor = 52800). Second, the Bayesian t-test against zero on the Group x Condition interaction on the Social SE suggested that there was anecdotal evidence ($BF = 2.5$) for favoring the alternative hypothesis. For this specific analysis, and with the significant p-value for the triple interaction ($F(1,74) = 5.55, p = 0.021$,

$\eta^2 = 0.070$), post hoc analysis to compute achieved power ($1-\beta$) revealed that power is below 80% (effect size $f = 0.27$, $(1-\beta) = 66\%$ for an $\alpha = 0.05$ and $N=76$).

Insert Figure 4 – Bayesian Results – Here

Discussion

The objective of this study was to determine whether and how one of the crucial mechanisms on which cooperative behaviors rests upon (Era, Candidi, et al., 2018; Knoblich & Sebanz, 2006), i.e. the ability to integrate one's own action representations with those of others, is modified under threat. To this end, dyads of participants jointly performed the Social Simon task while being exposed simultaneously (Common group) or not (Non-Common group) to alternating blocks of threat-of-screams or safety (Beaurenaut et al., 2020; Patel et al., 2017). Here, we adopted the action co-representation account (e.g. Sebanz et al., 2003; Sebanz, Knoblich, et al., 2006) to interpret our data (see other possible interpretations of our results are below). Our results are threefold. First, using both frequentist and Bayesian analyses, our results revealed that a Social SE emerged during Safe and Threat blocks, suggesting that co-representation abilities were maintained in both contexts. Second, we observed that sustained anxiety was lower in participants who performed the task in dyads as compared to a control group of 38 participants who performed the task alone, a phenomenon akin to social buffering. Third, when only one member of a dyad was under threat while the other was safe, the magnitude of the Social SE was slightly greater in threat compared to safe contexts, whereas it was of similar magnitude in safe and threat contexts when two members of a dyad shared the same experimental context. Altogether, these results suggest that self-other integration is maintained under threat and potentially increased when participants are exposed to an aversive situation on their own while the other participant is safe.

The Social Simon Effect has initially been proposed to assess self-other integration, underlined by an automatic co-representation of surrounding individuals' actions (Sebanz et al., 2003). Besides replicating previous findings from experiments that used the same task in classical (safe) contexts (Karlinsky et al., 2017), we further show that, when exposed to a moderate threat, the co-representation of surrounding others' actions is preserved. Alter-centric interference (Social SE) is known to be modulated by the interpersonal relationship between the members of the dyads. It is notably increased between lovers (Quintard, Jouffre, Croizet, & Bouquet, 2018), friendly and supportive co-actors (Hommel et al., 2009) as well as in-group members (McClung et al., 2013; Müller, Kühn, Van Baaren, et al., 2011) but

reduced under competitive context (Iani et al., 2011, 2014), following social exclusion (Costantini & Ferri, 2013) or when co-acting with a hostile individual (Hommel et al., 2009). By revealing that under threat, people continue to take into account the actions of others, our findings suggest that the capacity to act with the other member of the dyad is left intact by the threat. This is in line with converging evidence from fieldwork (Dezecache, 2015; Dezecache et al., 2020; Drury, Cocking, & Reicher, 2009b; Fahy & Proulx, 2009; Mawson, 2005) and behavioral research (e.g. Margittai et al., 2015; Tomova et al., 2020; von Dawans et al., 2019; von Dawans et al., 2012) that show that primary reactions to anticipated or experienced threats are social and affiliative rather than asocial and/or antisocial (Dezecache, 2015). We propose that affiliative tendencies under threat could be associated with the maintenance of self-other integration, an ability which could be crucial for survival by facilitating efficient action coordination (Török, Pomiechowska, Csibra, & Sebanz, 2019), cooperation and decisions (Schwenke, Dshemuchadse, Vesper, Bleichner, & Scherbaum, 2017; Wahn, Czeszumski, Labusch, Kingstone, & König, 2020) with others.

Affiliative tendencies under threat were suggested to be motivated by the fact that surrounding others can provide (a) a best estimate of the individual one's own emotional state (emotional comparison motives (Schachter, 1959)), (b) information regarding the nature of the threat (e.g., Kulik, Mahler, & Earnest, 1994), and/or (c) help reduce one's own anxiety level through comfort and mutual support (tend-and-befriends (Taylor, 2006)). While we did not look for dissociating these different possibilities, we observed that sustained anxiety (reflected by higher skin conductance and subjective anxiety levels in threat compared to safe blocks) was lower in participants who performed the Social Simon task in dyads (for both Common and Non-Common groups) as compared to those who performed the Classical Simon task on their own (see Supplementary Materials). This implies that the mere presence of a conspecific mitigated participants' anxiety responses during threat blocks, a phenomenon known as social buffering (O'Haire, McKenzie, Beck, & Slaughter, 2015; von Dawans et al., 2012). While reduced in the presence of conspecifics, anxiety responses in the members of dyads were still significantly higher during threat than safe blocks, suggesting that part of the anxiety responses to unpredictable threats is resistant to social buffering (see Kiyokawa, Kawai, & Takeuchi, 2018, for similar results in animals). These results concur with the idea that under threat, affiliative tendencies could be partly motivated by the fact that the presence of others reduces one's own anxiety level (fear-reduction effects that benefit both members of

the dyads). We further show here that affiliative tendencies and related social buffering effects are associated with the maintenance of self-other integration under threat.

To explore the situational determinants behind potential changes in action co-representation under threat, we ran a Common and the Non-common version of the Social Simon Task. Importantly, sustained anxiety was successfully and similarly elicited in both shared and non-shared situations. We observed that while the magnitude of the Social SE didn't differ in safe and threat contexts when two members of a dyad shared the same experimental context, when only one member of a dyad was under threat while the other was safe, a small difference in the magnitude of the Social SE was revealed between safe and threat contexts. Although we discuss this effect below, it should be taken with caution. Power and Bayesian analyses suggest that the level of evidence in favor of a difference of Social SE between the Non-Common and Common groups is anecdotal, and consequently this study should be replicated with a higher sample size to be fully conclusive regarding this difference between groups.

Moreover, before discussing the possible explanation for the above-mentioned effect, we would like to point out that several low-level explanations were discarded, thanks to the control group of 38 participant that performed the Simon Task in isolation. Several cognitive functions can indeed be affected by sustained anxiety, such as the individuals' state of vigilance (Öhman & Mineka, 2001) and associated attentional scope (Susskind et al., 2008), sensory processing (Grillon & Charney, 2011) as well as motor inhibition (Torrisi et al., 2016), which can themselves impact the performance of the Simon task. Yet, no differences in the classical Simon effect were observed between threat and safe contexts (Alone group), suggesting that the observed difference between the Non-Common and Common groups is more likely to be related to the social context than low-level modulations.

One possible explanation for this effect could be that social partners are appraised as relevant cues to meet safety. Affiliative tendencies were suggested to depend on the perceived or anticipated benefit and damage of being with another to one's own ability to cope with the current anxiety-inducing context (Rofé, 1984). Individuals do spontaneously track their partner's abilities and/or resources to act (Doerrfeld et al., 2012; Low et al., 2020), seek out information and affiliation from more fortunate (upward contacts) rather than less fortunate others (Taylor & Lobel, 1989), and show decreased affiliative tendencies toward individuals that are the most exposed to threat (Dezecache et al., 2017). Altogether, this suggest that facing alone a threat may increase affiliative tendencies toward safe individuals, an increase which could promote social strategies essential for one's own survival.

This interpretation that co-partners (notably safe ones) represent an available resource of social support remains however speculative as different criticisms can be brought. The first is that the Social Simon Task consists of two independent sub-tasks for each participant. The performance of one player does not influence the performance of the other and does not influence the probability of receiving a scream. In addition, participants were forbidden to communicate with one another. As a result, our experimental setting did not allow any direct form of assistance between participants. Nevertheless, it is not because participants take part in a given task that their cognitive system solely focus on task-related solutions and many effects in social cognition are based on beliefs that can be easily induced. For example, presenting an image of a gaze is sufficient to induce a belief of being observed and to impact several cognitive functions (Conty, Gimmig, Belletier, George, & Huguet, 2010; Haley & Fessler, 2005; Hazem, Beaudenaut, George, & Conty, 2018; Hazem, George, Baltazar, & Conty, 2017). Still, more direct evidence should be provided to validate our interpretation, by for example, replicating this study in the presence of a non-human agent or in the presence of a confederate who would be injured/constrained vs. human/healthy/unconstrained.

The mechanisms underlying the interference observed during the Social or Joint Simon task and their social nature are debated. Besides the action co-representation account (Sebanz et al., 2003) that we first adopted to interpret our data, it has also been suggested that the Social SE could be explained within the referential coding (Dolk et al., 2013, Dolk et al., 2014 for the review) or the social facilitation (Belletier, Normand, & Huguet, 2019) frameworks.

The referential coding theory suggests that the presence of a co-partner provides spatial, perceptual or conceptual reference frames used by the participant to code their actions. Hence, the proponents of action co-representation account argue for the social nature of the task, while those of the referential coding account propose that any sufficiently salient event, irrespective of its social nature, can prompt an interference. Past experiments provided several evidence that interpersonal social factors, such as social status (Aquino et al., 2015), group membership (McClung et al., 2013) or perceived interpersonal closeness (Shafaei, Bahrami, & Vaziri-Pashkam, 2019), influenced the magnitude of the Joint Simon effect. Proponents of the referential coding framework suggest that the above-mentioned social effects are related to the fact that the size of the Joint Simon effect is an indicator of the similarity between self- and other-generated alternative events. Within this framework, one should expect the magnitude of the Joint Simon effect to be greater in the Common group (with high self-other similarity) compared to Non-Common one (with low self-other similarity). Our findings are at

odd with this prediction. We therefore believe that the referential coding framework and the similarity explanation cannot fully explain the present results.

Another potential explanation of our results is that the joint Simon effect is the result of demands in executive attention induced by the presence of conspecifics (rather than the representation of their actions). Under this account, the presence of other individuals consumes part of the executive-control resources necessary to inhibit incorrect dominant responses (Belletier et al., 2019). Of interest, it has been shown that the presence of threatening individuals (socio-evaluative threat (Belletier et al., 2015) or dominant conspecifics (Huguet, Barbet, Belletier, Monteil, & Fagot, 2014)) reduces participants' executive attention allocated to the ongoing task. Proponents assume that such decrease supports the view that surrounding social partners can receive special monitoring, relevant for survival. Within this perspective, the size of Joint SE is dependent on the amount of cognitive resources allocated to low-level visuo-motor processes, themselves affected by high-order belief about one's social environment (i.e. the presence of conspecifics). We are not in position to disentangle between accounts (i.e. Joint SE reflecting a reduction of executive attention or action competitions at representation level). This said, both proposed that others' monitoring (respectively the presence or the action of others) is responsible for the induction and the modulation of the Joint SE. In other words, the Joint SE is associated with the basic inference that another biological agent is taking part in the task is carried out. Thus, the ability to monitor others is maintained under threat and possibly boosted by the presence of a safe co-partners.

We should acknowledge limitations that we expect future research to overcome. First, they were conducted in a between-subject design, which was favored in the past to investigate Social SE (Costantini & Ferri, 2013; Kuhbandner et al., 2010), as the social context of an experimental condition can contaminate the subsequent one due to potential long-term effects (Chadwick, Metzler, Tijus, Armony, & Grèzes, 2019; Iani et al., 2014). Still, part of our results could be explained by random variations from the different sampling populations. While we cannot control for all possible variables, we checked that Common and Non-Common groups didn't significantly differ in their levels of anxiety traits (LSAS, STAI-T), anxiety state (STAI-E) and induced anxiety (SCL, subjective anxiety, debriefing scores). Second, as we only tested same gender dyads, mixed gender dyads should be looked at. Third, more evidence is needed to support the Fate by Condition interaction. Future research should specifically tackle the possible mechanisms and motives behind this increase, notably the

potential role of co-representation in recruiting social support. Finally, while laboratory experiments clearly allow investigating the impact of moderate threat on socio-cognitive mechanism in controlled environments (Kinader et al., 2014), one may still question their validity to address behavioral responses in real life situations where individuals are at risk of death.

Overall, the present work strongly supports the idea that, under threat, affiliative tendencies prevail, by showing that action co-representation (or at least the monitoring of the partner's presence) is maintained and possibly boosted in the presence of safe individuals. We further observed that the mere presence of a conspecific mitigated participants' anxiety responses during threat blocks. We discussed the possibility that affiliation function is to recruit social support to maximize individual's survival, but further experiments are needed before such conclusion can be firmly drawn. Despite its limitations, our study provides a crucial first step into studying real-time reactions to threatening situations in a social context. This is necessary to comprehensively understand the nature and dynamics of human social behavior in the face of danger.

Author notes

Author contributions

M.B., J.G. and G.D. designed the study; M.B. collected the data; M.B. performed the analysis; M.B., J.G. and G.D. wrote the first draft of the manuscript. All authors reviewed and approved the final manuscript.

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Competing interests

The authors declare no competing financial interests.

Supplementary material

Data are available on OSF:

https://osf.io/tb9sk/?view_only=0dd2445b91c9422c9735119286645fb7

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Figure legends

Figure 1. Experimental Design. (A) Experimental Settings. Participants in dyads performed the Social Simon task, while either sharing (Common) or not (Non-Common) the experimental context. The blue color bands on the screen indicated to participants that they could be exposed at any time to distress screams (threat blocks) while green color bands indicated that no such screams will be delivered (safe blocks). Participant, whether from the Common or the Non-Common group, performed the Social Simon task alternating threat and safe blocks, and the nature of the first block was counterbalanced across participants. Each participant was responsible for one color cue (e.g. participant 1 – violet, participant 2 - grey) by pressing the associated key-press (e.g. participant 1 – left, participant 2 - right). (B) Temporal organization of one block (here for the Non-Common Group). Each block began with a one-minute baseline to measure participants' skin conductance before the block. A written sentence was then presented for 10 sec, providing information about the upcoming nature of the block (Safe or Threat) for each participant. At the end of the Social Simon task, participants were requested to rate their anxiety level during the block on a continuous scale. (C) Temporal organization of a trial (here for the Non-Common Group). Each trial started with a fixation screen for 500ms. A colored cue then appeared for only 150ms followed by the presentation of a screen without the color cue until participant's response. Skin conductance activity was measured throughout the task and compared to the Baseline.

Figure 2. Skin Conductance level and Subjective reports of anxiety. P-value for t-tests contrasting threat against safe blocks within each group are provided.

Figure 3. Social Simon Effect (Social SE) for the Common and the Non-Common groups. Points represent individual data. Distribution in the upper part of each plot represents the difference in Social SE between Threat and Safe blocks and the black line the median of this distribution. The distribution is center to zero for the Common Group while it is shifted toward positive values for the Non-Common Group. *** = $p < 0.001$; ** = $p < 0.01$; * = $p < 0.05$; n.s. = $p > 0.05$.

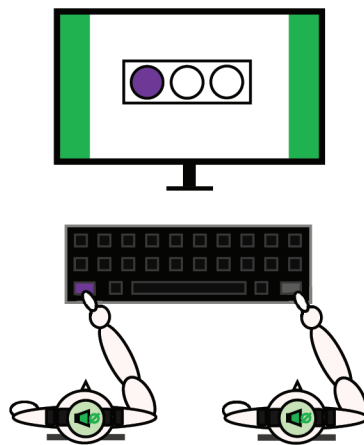
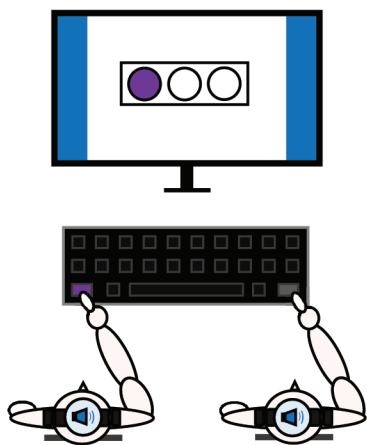
Figure 4. Sequential analysis plots of the Bayes factors for the Social SE in Safe blocks (left), Threat blocks (middle) and Group-by-Condition Interaction (right).

A

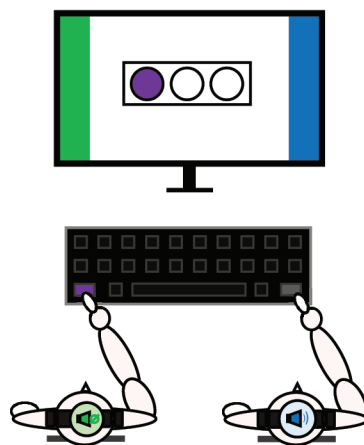
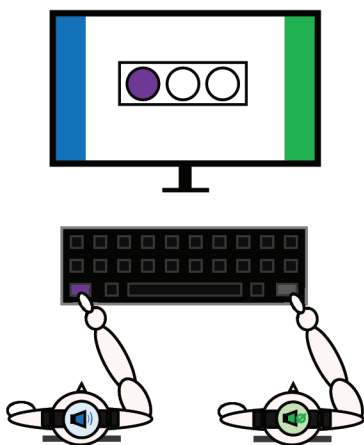
Block n

Block n + 1

Common Group



Non-Common Group



B

SCL Baseline

Condition

Readying

Social Simon

Anxiety Scale

Stabilisation of
the signalP1 : Threat Block
P2 : Safe Block

Be ready !

Anxious ?
+

60s

10s

3s

~ 3min

Until answer

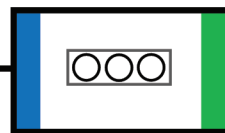
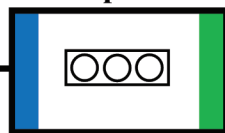
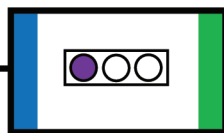
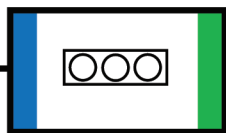
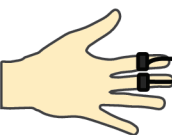
C

Fixation

Cue

Response

ITI



500ms

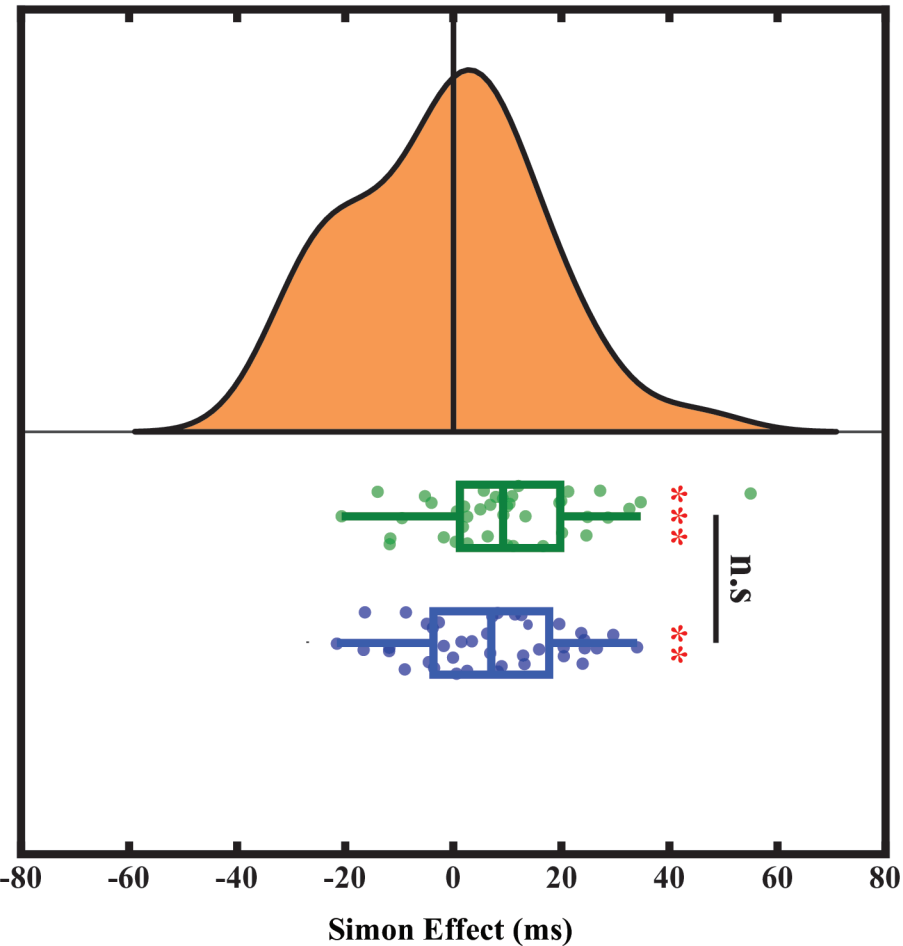
150ms

Until Response

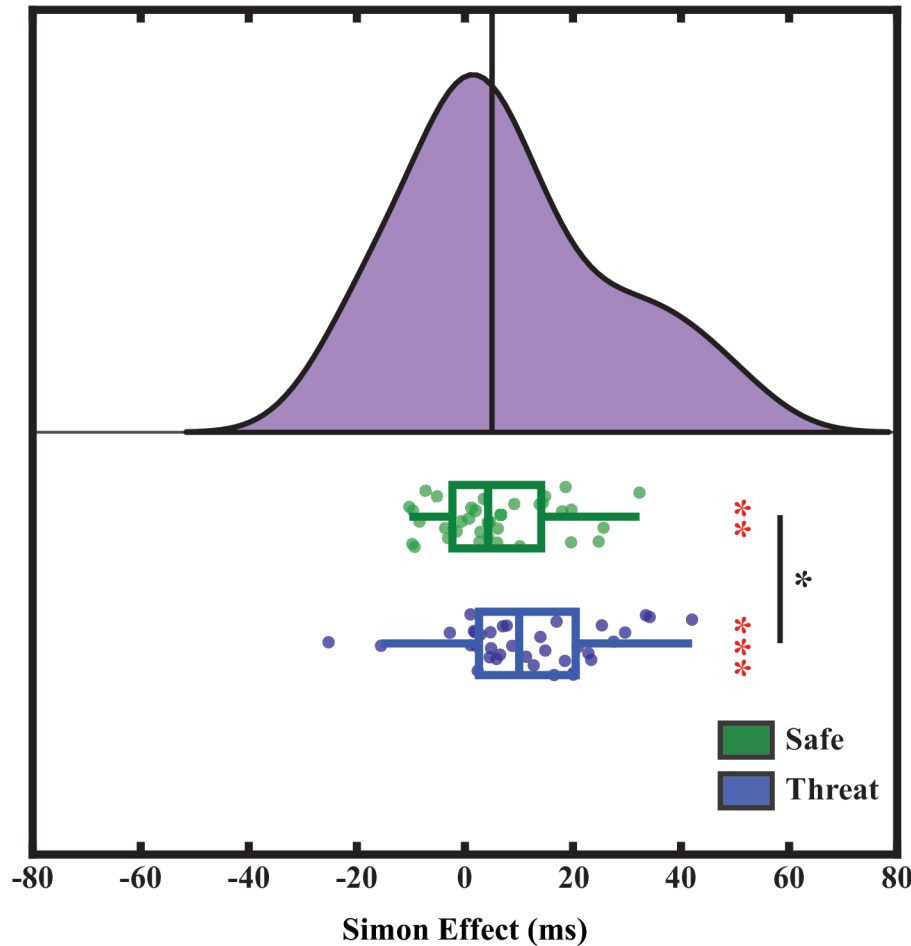
1000ms

SKIN CONDUCTANCE LEVEL				SUBJECTIVE ANXIETY			
Group	Condition	Mean ± SE	p-value	Group	Condition	Mean ± SE	p-value
Common	Threat	0.48 μS ± 0.33 μS	0.007	Common	Threat	37.30 ± 2.96	< 0.001
	Safe	- 0.82 μS ± 0.58 μS			Safe	26.75 ± 2.51	
NonCommon	Threat	0.072 μS ± 0.44 μS	0.017	NonCommon	Threat	35.74 ± 3.69	< 0.001
	Safe	- 0.92 μS ± 0.52 μS			Safe	23.74 ± 3.02	

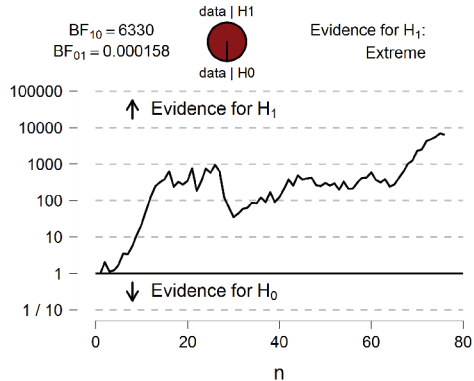
Common Group



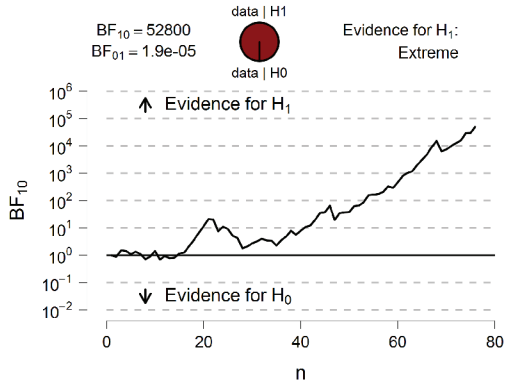
Non-Common Group



SE_Safe



SE_Threat



Group x Condition

