**Mapping the Psychophysiology of Commitment**

**Summary**

As humans, we are remarkable for the versatility and flexibility with which we carry out joint actions. From cooking meals to managing pandemics and combatting climate change, our affinity for joint action enables us to achieve our goals efficiently, and to achieve goals that could not otherwise be achieved (Sebanz et al., 2006; Tomasello, 2009; Melis & Semmann, 2010). But it also requires us to rely on each other to persist in contributing to joint actions even in the face of fluctuations in our own short-term interests. In previous research, it has been shown that the motivation to remain engaged in joint actions and to resist tempting alternative options and distractions is governed by a sense of commitment, and that this sense of commitment is sensitive to cues that another agent is expecting one to perform one’s contribution, and may be relying on this expectation (Michael, 2022; Michael, Sebanz, & Knoblich, 2016a; Dana, 2006; Heintz et al., 2015; Sugden, 2000; MacCormick & Raz, 1972; Scanlon, 1998).

However, the psychophysiological processes underlying the sense of commitment remain unclear. In the current project, we address this gap by conducting two empirical studies which investigate how perceptual cues of a joint action partner’s expectations and reliance modulate psychophysiological activity to bolster commitment, and by writing one theoretical paper which synthesizes the results and presents a framework for mapping out the psychophysiology of the sense of commitment. Each of the two studies combines EEG with behavioral measures, as well as questionnaires, to investigate a distinct stage of processing at which the sense of commitment may be reflected in neurophysiological activity.

Study 1 probes the psychophysiological processes through which a sense of commitment is elicited. We test the hypothesis that the perception of a joint action partner’s investment of effort leads participants to form integrated joint action plans, and accordingly enhances their motor representation of the partner’s actions.

Study 2 probes the effects of the sense of commitment upon motivation to persist in joint action. As a starting point, we draw upon a distinction between two forms which this may take (Michael, 2022). The first form may be dubbed *gritted teeth commitment.* This is the form of commitment you experience when you find yourself bored or distracted, or otherwise tempted to abandon a goal, but nevertheless force yourself to persevere, and to resist temptations and distractions. We hypothesize that this involves the deployment of executive control mechanisms (e.g. inhibitory control and supervisory attentional control) to maintain task focus and to avoid temptations and distractions. The second form may be dubbed *engaged commitment*. This is the form of commitment you experience when you are so immersed in pursuing a goal that you do not notice temptations or distractions in the first place, and therefore do not need to force yourself to ignore or resist them. We hypothesize that this boosts the relative salience and attractiveness of task-relevant information, making task-irrelevant stimuli in the environment and task-irrelevant thoughts less tempting or distracting than they otherwise would be.

**Technical Description**

**Literature Review**

In recent years, there has been a surge of research investigating the sense of commitment in joint action. This research has identified key factors which boost the sense of commitment. For example, it has been shown that participants expect agents to resist outside options when observing joint actions with a high degree of coordination compared to low coordination (Michael et al., 2016b); that participants are more committed to partners who are willing to adapt their movements to send informative signals during a joint task (McEllin & Michael, 2022); and that a partner’s investment of costs such as effort or time may also signal that she expects and is relying upon one to remain engaged, which in turn motivates one to persist until the goal is reached (Székely & Michael, 2018; Chennells & Michael, 2018; Bonalumi, Isella, & Michael, 2019; McEllin & Michael, 2022).

While no research has yet investigated the psychophysiological processes whereby factors such as coordination, adaptation and the investment of costs elicit a sense of commitment, there is suggestive evidence from a related line of research. In particular, Clarke et al. (2019, cf. Sacheli, 2018; della Gatta et al., 2017) reported evidence that when two agents have a shared goal, they represent their partner’s action motorically, and integrate it with their motor representation of their own action. Based on this research, we hypothesize that the perception of a joint action partner’s investment of effort leads participants to form integrated joint action plans, and accordingly enhances their motor representation of the partner’s actions. To test this using EEG (**in Study 1**), we will record alpha-mu suppression, which is a neural marker of shared motor representations and interpersonal coordination (Konvalinka et al., 2014; Keller, Novembre, & Hove, 2016; Kourtis et al., 2019; Dumas et al., 2020). By measuring alpha-mu suppression while participants coordinate with a partner, we will ascertain whether participants integrate motor representations of their own and their partner’s actions. We will also measure two behavioral markers of commitment: participants’ generosity in sharing rewards with the partner and their willingness to persist in performing the joint task with the partner. This will enable us to ascertain whether alpha-mu suppression is correlated with behavioral markers of commitment.

There is also a dearth of research investigating how the sense of commitment stabilizes agents’ motivation in joint action. One exception is a behavioral study conducted by Michael’s group (Székely et al, in prep), using the sustained attention to response task (Manly et al., 1999; Smallwood et al., 2004). This study provides support for the hypothesis that the perception of a joint action partner’s effort leads to the increased engagement of executive control mechanisms (inhibitory control and supervisory attentional control) to maintain task focus and to avoid temptations and distractions. To investigate the psychophysiological processes underpinning the effects of the sense of commitment upon motivation, we will (**in Study 2**) present participants with tempting opportunities to defect from a joint action, and use EEG to measure their readiness potential as an indication of the degree to which they are tempted. In so doing, we draw upon a study in which Panasiti et al. (2014) found that choosing to lie during a temptation-to-lie game with a virtual partner was associated with decreased motor readiness, an event-related potential component that is linked to motor preparation of self-determined actions. This reduction was less extensive in manipulative participants and greater in those who cared highly about their impression management. We will also include a behavioral measure of commitment, namely participants’ resistance to a tempting defect option. This will enable us to ascertain to what extent readiness potential is correlated with a key behavioral marker of commitment.

**Methods**

Studies 1 and 2 implement two distinct experimental paradigms, each of which is adapted from behavioral studies successfully used in previous research on joint action. The two experimental designs complement each other insofar as the design in Study 1 has greater ecological validity (involving interaction with a real partner), whereas the design in Study 2 permits greater experimental control and a greater number of trials. In addition, the use of two distinct paradigms affords us with a more firm basis for generalization based on the findings.

**Study 1**

The purpose of Study 1 is to discern whether sensorimotor communication and self-other integration between partners during joint action, indexed by alpha-mu suppression in sensorimotor areas, are associated with a stronger tendency of the partners to remain committed to the joint action.

It has been suggested that in carrying out joint actions, individuals can either utilize sensorimotor signals sent by the partner to perform real-time coordination (Dumas et al., 2010, 2020; Konvalinka et al., 2010, 2014; Keller et al., 2014), or rely on their internal model of the partner’s action (Wolpert et al., 2003; Kourtis et al., 2013; Pezzulo et al., 2017; Fanghella et al., 2021). Although interpersonal coordination is usually grounded in a combination of different strategies (Knoblich & Sebanz, 2008), these two mechanisms (real-time self-other integration and predictions of others’ actions based on internal models) are nevertheless distinct (Novembre et al., 2016; Satta et al., 2017). Interestingly, there is evidence that these two mechanisms are associated with different modulations of alpha-mu suppression; specifically, alpha-mu suppression is enhanced during real-time interpersonal coordination, and it is reduced when individuals rely on their internal models of action (Novembre et al., 2016).

To test whether sensorimotor signaling and interpersonal integration are associated with enhanced commitment toward joint actions, participants will engage in a joint task requiring motor coordination with two different partners (both confederates). The task is adapted from one developed by Satta and colleagues (Satta et al., 2017). Each player (the participant and the confederate) will move a cursor (a red or a green character) with an isometric joystick to bring an object (a shovel) toward a target (an igloo). According to the condition (signaling/no signaling), one of the confederates will send sensorimotor signals to the partner and adjust to the partner’s behavior to facilitate interpersonal coordination. Conversely, the other confederate will not send sensorimotor signals nor adjust to the co-actor. Instead, the confederate will move the cursor in a regular and predictable way, enabling interpersonal coordination (likely to be based on internal models). Each participant will perform the joint action with both confederates (signaling/no signaling), with the order being counterbalanced across participants. In a *parallel* control condition (della Gatta et al., 2017; Barchiesi et al., 2022), the two players are required to bring their own individual object to the target.

Each condition (signaling condition; no signaling condition, parallel condition) will be performed in counterbalanced blocks, with each block consisting of 80 trials (subdivided into 10 mini-blocks of 8 trials each). At the beginning of each block, participants will perform two training sessions, one for the joint version of the task and one for the parallel version.

We also include two behavioral dependent variables: generosity and persistence. To measure generosity, at the end of each mini-block in the signaling and no signaling conditions, participants will be asked if they want to share their points with the partner. To measure persistence, at the end of each mini-block in all conditions, they will express their preference as to whether to continue in the joint (or parallel) version of the task or to switch to the other version. Participants will be told that their preference toward continuing in the same version or switching to the other will make their favorite option more likely, but not certain. By doing so, we will be able to control the number of mini-blocks administered for each condition (e.g., if they have repeatedly chosen to persist, they will be administered the control condition regardless of their choice in order to ensure appropriate counterbalancing). Moreover, they will be informed that the partner is not aware that the participant can express their preference with respect to the joint or parallel version of the task, and that the partner will not have the opportunity to express their own preference.

*Predictions:*

1. In the signaling condition (high coordination), participants will rely on the co-actor’s motor cues to coordinate their behavior in real-time to successfully execute the joint action.
2. This behavior will be associated with enhanced sensorimotor alpha-mu suppression during motor preparation/execution.
3. Higher coordination and self-other integration (indexed by neural alpha suppression) will trigger increased generosity (participants will share more points with their co-actor) and commitment toward the joint action (participants will choose to continue with the joint version, rather than switching to the parallel version). This prediction is based on a) evidence showing that the perception of the partner’s effort to send informative signals triggers stronger generosity and b) evidence showing that higher coordination is associated with a stronger sense of commitment (Michael et al., 2016b).
4. In the no-signaling condition (low coordination), participants will mostly rely on their internal model of the co-actor’s movement to predict and accordingly coordinate their behavior.
5. This will trigger reduced alpha-mu suppression, compared to the high coordination condition. In the parallel (control) condition, we expect to observe the least alpha-mu suppression.
6. Lower coordination will be associated with reduced generosity and persistence toward the joint action partner, compared to the high coordination condition.

**Study 2**

The coordination task in study 2 is adapted from a behavioural study by McEllin & Michael (2022). It requires participants and their partners to move their respective markers that are located at opposite sides of the screen (e.g., the participant's marker is on the centre-left and their partner’s marker is on the centre-right) to one of two targets stacked horizontally in the centre of the screen. Both participants and partners receive points (which translates to a bonus at the end of the experiment) depending on how quickly they reach the correct target. The participant is instructed to respond to the correct target with a button press, whilst their partner responds by dragging their marker to the correct location with their mouse, with participants being informed that their partner always knows the correct location of the target. Participants complete this task with three separate (virtual) partners, who are programmed to appear as if they were picking up the target with their mouse and dragging it to the correct target, with the kinematic trajectory of the partner’s movement depending on the trial type. For *no-signal trials,* the partner moves in such a manner that their kinematics does not carry a signal with respect to the location of the correct target. For *useful-signal* trials the partner’s movements displays a strong curve towards the correct target (e.g., Pezzulo & Dindo, 2011), thus allowing the participant to quickly disambiguate the target that they are moving to. We also implement *redundant-signal* trials in which the partner’s movements are the same as in the useful-signal trials, but with the participant being informed about the location of the correct target (participants are led to believe that their partners do not know they were informed). This condition allows us to probe whether in our task sensorimotor communication facilitates commitment because of the utility of the signal itself or because the signal reflects a willingness to incur effort costs for the good of the interaction (cf. a preference for those who incur costs regardless of the outcome in an economic game, Eisenbruch & Roney, 2017; Raihani & Barclay, 2016)

After each trial they receive a fixed equal reward, but they have the opportunity to defect, i.e. to negate the round and instead receive a higher individual reward, unbeknownst to the partner. By varying the size of the tempting individual reward, we identify the threshold beyond which each participant is more than 50% likely to defect. We also measure the overall proportion of defections.

Each condition (*useful-signal*; *redundant-signal; no-signal trials*) will be performed in counterbalanced blocks, with each block consisting of 160 trials (subdivided into 20 mini-blocks of 8 trials each). At the beginning of the experiment, participants will perform one practice block with no signaling.

Importantly, we will measure Readiness Potential (RP) by means of EEG after asking participants if they want to defect or not. Participants will be instructed to press a button if they choose to negate the trial (defect), and otherwise to remain still and wait for the next trial. During this 3000-millisecond response phase, we will measure electrophysiological activity from each participant.

*Predictions:*

1.We predict lowest defection rates in the *useful-signal* condition, followed by the *redundant-signal condition, and highest defection rates in the no-signal condition.*

2. If our manipulation (i.e. the use of signaling, and especially useful signaling) lowers defection rates by triggering *gritted teeth commitment*, then we should expect to see a stronger RP on trials closest to the threshold. Indeed, if participants are tempted to defect, we predict that we will observe an RP (readiness potential associated with initiating an action, e.g., pressing the button to defect) even if they ultimately decide not to defect (i.e., not to press the button). This prediction is supported by previous studies showing that RPs are observed also in cases where participants finally decide not to perform a movement (Trevena & Miller, 2010; Schultze-Kraft et al., 2016). According to this hypothesis, patterns of EEG activity corresponding to early RP on trials in which the participant defects should be similar to patterns observed on trials in which they do not defect (because they have been tempted to defect but resisted through gritted teeth).

3. Conversely, if our manipulation lowers defection rates by triggering *engaged commitment*, then we should expect to see reduced or even absent RP on trials in which the participant chooses not to defect, indicating that they were not tempted to do so. (i.e., reflecting an early filtering process rather than later, top-down inhibitory mechanism (Bryce et al., 2011).

**Studies 1 and 2**

After participants have completed the task in each study, they will complete the 30-item self-construal questionnaire (Singelis, 1994: [30-item Self-Construal Scale](https://sparqtools.org/mobility-measure/self-construal-scale/#all-survey-questions)), enabling us to probe whether differences in self-reported interdependence are correlated with differences in our behavioral and/or neurophysiological measures.

**Theoretical paper**

The theoretical paper will synthesize and interpret the results of studies 1 and 2, exploring possible relationships between gritted teeth commitment and engaged commitment. The most straightforward hypothesis concerning this relationship is that these two forms of commitment are mutually exclusive: either the intrinsic reward value of the task is enhanced (engaged commitment), in which case the need for executive control is reduced, or executive control is enhanced (gritted teeth commitment), stabilizing task focus and performance despite a reduction in the intrinsic reward value of a task. But there are also many ways in which the two forms of commitment may support each other. For example, gritted teeth commitment may work by focusing attention on aspects of a task which are rewarding, leading to an increase in the intrinsic reward value of a task. Indeed, it has been argued that executive control can serve to bias lower-level processing in working memory (Baddeley, 1986; Christensen, Sutton, & McIlwain, 2016). Likewise, by enhancing the intrinsic reward value of a task, engaged commitment may also lead to the recruitment of executive resources to stabilize or boost performance. The paper will spell out these theoretical options and evaluate them in light of existing evidence, and identify testable predictions to provide direction for future research.

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**Budget**

64-channel EEG cap and amplifier module to be used with the our existing amplifier: 15,000

Postdoc for 18 months: 45,000å