Cognition 161 (2017) 60–65

Contents lists available at ScienceDirect

Cognition

journal homepage: www.elsevier.com/locate/COGNIT

Brief article

The predictability of a partner's actions modulates the sense of joint agency

Nicole K. Bolt, Janeen D. Loehr *

Department of Psychology, University of Saskatchewan, 9 Campus Drive, Saskatoon, SK S7N 5A5, Canada

ARTICLE INFO

Article history:
Received 23 June 2016
Revised 4 January 2017
Accepted 7 January 2017

Keywords:
Agency
Joint action
Interpersonal coordination
Joint agency
Action prediction

ABSTRACT

When people coordinate their actions with others, they experience a sense of joint agency, i.e., shared control over actions and their consequences. The current study examined whether the predictability of others' actions modulates joint agency. Each participant coordinated with two confederate partners to produce tone sequences that matched a metronome pace. The timing of the confederates' actions was manipulated so that one partner's actions were highly predictable in time and the other's less predictable. After each sequence, participants rated their experience of joint agency on a scale from shared to independent control. People felt more shared control when they coordinated with the more predictable partner, even after controlling for their own performance accuracy and variability. Thus, people rely on predictions of others' actions to derive a sense of joint agency during interpersonal coordination.

1. Introduction

When people perform actions, they experience a *sense of agency*, i.e., control over actions and their consequences (Haggard & Tsakiris, 2009). Considerable research has established that predictive mechanisms play a critical role in the sense of agency (Haggard & Eitam, 2015; Synofzik, Vosgerau, & Voss, 2013). However, this research has focused almost exclusively on people performing actions alone. Little research has examined the sense of agency when people perform joint actions, i.e., coordinate their actions with others to achieve a shared goal (Sebanz, Bekkering, & Knoblich, 2006). Joint actions raise interesting questions about agency because they require people to make predictions about not only their own but also their co-performers' actions (Vesper, Butterfill, Knoblich, & Sebanz, 2010). Philosophers have proposed that people may experience a sense of *joint agency*, or shared control over actions and effects, during joint action (Dokic, 2010; Pacherie, 2012; Seemann, 2009) and that joint agency may be driven in part by people's ability to predict their co-performers' actions (Pacherie, 2012). The current study presents the first direct empirical investigation of this hypothesis.

Experiences of agency during solo action (*self-agency*) depend on comparisons between prior predictions and post hoc information about actions (Synofzik et al., 2013), at multiple levels of action specification (Pacherie, 2008). The closer the match between the predicted and actual consequences of an action, the stronger the sense of self-agency. At the sensorimotor level, internal predictions about the sensory consequences of actions, generated from efference copies of motor commands, are compared with actual sensory consequences (Frith, Blakemore, & Wolpert, 2000). At the perceptual level, self-agency relies in part on contiguity between actions and perceptual consequences. For example, introducing delays between taps and the tones they elicit reduces self-agency (Sato & Yasuda, 2005). Recent models of self-agency emphasize that cues at each level are weighted differently depending on their availability and reliability (Moore & Fletcher, 2012; Synofzik et al., 2013).

Successful joint action requires people to make predictions not only about their own actions (*self-predictions*), but also about their partners' actions (*other-predictions*) and the joint action (*joint-predictions*; Pacherie, 2012). During joint action, people predict the consequences of others' actions (Kourtis, Sebanz, & Knoblich, 2013; Loehr, Kourtis, Vesper, Sebanz, & Knoblich, 2013) and integrate simulations of different parts of the joint action (Vesper, Knoblich, & Sebanz, 2014). Thus, they are able to compare other- and joint-predictions with actual outcomes (Keller, Novembre, & Loehr, 2016; Wolpert, Doya, & Kawato, 2003). Because people have access to perceptual but not sensory reafferent information about their partners' actions, perceptual predictions likely have a greater role than sensorimotor predictions in the experience of agency during joint action (Pacherie, 2012; van der Wel & Knoblich, 2013).

Pacherie (2012) proposed that the sense of joint agency depends on the accuracy of self-, other-, and joint-predictions. Indirect support for this account comes from findings that ratings

* Corresponding author.
E-mail addresses: nicole.bolt@usask.ca (N.K. Bolt), janeen.loehr@usask.ca (J.D. Loehr).

http://dx.doi.org/10.1016/j.cognition.2017.01.004
0010-0277/

of control over a joint action are positively correlated with the smoothness of both one's own and a partner's movements (van der Wel, 2015) and with pair-level task accuracy (Dewey, Pacherie, & Knoblich, 2014; van der Wel, Sebanz, & Knoblich, 2012). However, the rating scales used in these studies were ambiguous as to whether they referred to self-agency, joint agency, or both (Dewey et al., 2014). When people are specifically asked to rate joint agency, factors that increase coordination between partners increase the strength of joint agency (Bolt, Poncelet, Schultz, & Loehr, 2016). This also indirectly supports Pacherie's (2012) proposal, because the better people are able to predict their partners' actions, the better coordinated they are (Keller, Knoblich, & Repp, 2007; Loehr & Palmer, 2011). The current study sought to provide direct evidence for the hypothesis that joint agency depends on the accuracy of other-predictions. We asked participants to rate their feelings of joint agency after coordinating with two partners, the timing of whose actions we manipulated so that one partner's actions were highly predictable in time and the other partner's less predictable. We expected that people would experience stronger joint agency when they coordinated with the more predictable partner. Alternatively, if joint agency is driven primarily by sensorimotor predictions about one's own actions, then partner predictability should have little effect on joint agency.

2. Method

2.1. Participants

Forty-eight adults (17 male, $M_{age} = 19.69$, $SD = 2.18$) participated in the study. Ethical approval was obtained from the institutional review board. Participants gave informed consent and were compensated with course credit.

2.2. Design

Participants coordinated their actions with confederate partners[1] to produce 8-tone sequences that matched a metronome pace (Fig. 1). Partner predictability was manipulated within-subjects. Each participant was paired with a *high-predictability* and a *low-predictability* partner. The partners' inter-tone intervals (ITIs) were selected from uniform distributions that ranged in 1 ms increments from 490 to 510 ms (i.e., the 500 ms metronome pace ± 10 ms) and 440 to 560 ms (500 ± 60 ms), respectively.

2.3. Procedure

The confederates and participant arrived at the experiment at approximately the same time. They were instructed that they would coordinate with each other in different pairings and then drew numbers to decide who would sit on the right. In reality, the participant always drew 1 and sat on the right, one confederate indicated that they had drawn 2 and sat on the left, and the other confederate was instructed to leave the room. The two confederates switched places halfway through the experiment. We counterbalanced across participants whether they coordinated with the high- or low-predictability partner first and the assignment of confederates to predictability.

Partners sat on the same side of a table with a computer screen centered between them ~60 cm from the table edge. An Interlink force-sensitive resister (FSR; 3.81 cm^2) was placed in front of each partner ~30 cm from table edge. Only the participant's FSR was operational. Participants tapped the FSR with the index finger of their dominant hand. The FSR registered taps without providing auditory feedback. Each tap triggered a 1000 Hz tone (100 ms duration, 10 ms rise/fall) via a WaveShield connected to an Arduino microcontroller, ensuring an ~3 ms tap-to-tone latency (Schultz & van Vugt, 2015). The Arduinos signaled PsychoPy software (Peirce, 2007) when a tap was registered. PsychoPy recorded the taps and presented the remaining stimuli, including the metronome (880 Hz) and confederate (1000 Hz) tones. Tones were presented through speakers on both sides of the screen. Number keypads were placed beside each FSR and a 40 cm occluder was centered between the FSRs to prevent partners from seeing each other's taps and ratings.

Each half of the experiment began with two trials during which the experimenter explained the task. Partners then performed 5 training trials and 6 blocks of 5 test trials. Both partners provided agency ratings after every test trial. One partner was the leader (produced the first sequence tone) for all trials in a block. Partners alternated between leader and follower across blocks (including training). We counterbalanced whether the participant was the leader on the first block across participants.[2] At the beginning of each block, instructions presented onscreen indicated which partner was the leader.

Each trial began with a 2000 ms visual cue that reminded participants who was the leader. A fixation cross then appeared and remained in the center of the screen until the last sequence tone was produced. Four metronome tones were presented at 500 ms intervals beginning 500 ms after fixation onset. Partners were instructed to alternate their actions to produce an 8-tone sequence while maintaining the metronome pace. Confederates produced tapping movements that did not contact the FSR. After each sequence, both partners rated their "feelings of control over the timing of the sequence" on a scale from 01 ("shared control") to 99 ("independent control"). Scale endpoints were chosen based on philosophical definitions of joint agency (see Bolt et al., 2016). Zero was included as the first digit for ratings <10 to prevent partners from guessing each other's ratings based on number of keystrokes. Partners entered their ratings in random order, determined separately for each trial and signaled by which side of the screen the rating instructions appeared on first.

After the participant had coordinated with the second confederate, both were told that the coordination phase was complete. They were given demographics questionnaires and the experimenter left the room ostensibly to give the other participant the questionnaire. Next, the experimenter announced that there were verbal questions to be answered individually, and the confederate was instructed to leave the room first. Participants then completed a debriefing that probed what they thought the purpose of the experiment was, general suspicions, and whether they noticed differences between their partners (Bargh & Chartrand, 2000). One participant guessed the confederate manipulation and was replaced. Most participants (39/48) reported noticing a difference between their partners (e.g., one was better at the task).

2.4. Data analysis

2.4.1. Errors

Trials with rating errors (partners entered their ratings in the wrong order or an invalid rating of 0 or >99; 2.2%) were excluded from analysis. Trials with sequence errors were also excluded from analysis. Because the computer produced a confederate tone after each of the participant's taps and/or the last pacing tone, the correct sequence was always produced. Sequence errors were therefore identified by unusually short or long ITIs (3*SD* above or

[1] None of the participants knew either confederate before the experiment.

[2] Because leader/follower roles have little influence on joint agency in the coordination task used here (see Bolt et al., 2016), we counterbalanced role but did not analyze its influence further.

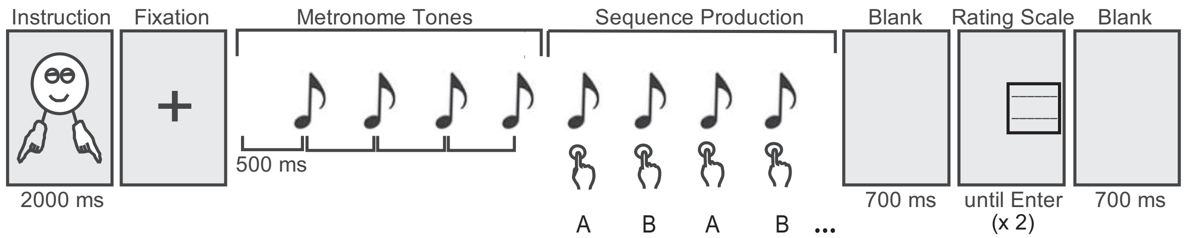

Fig. 1. Schematic illustration of the coordination task. Following instructions and fixation, participants heard a metronome (i.e., a series of isochronous pacing tones, illustrated by eighth note symbols) and then alternated their actions to produce a sequence of 8 tones (illustrated by combined button press and eighth note symbols, labeled A and B for the two partners). After producing the last tone, each partner provided an agency rating.

below the mean ITI across all trials for a given participant; 10.56%), which occurred, for example, if a participant attempted to produce the first sequence tone when the confederate was the leader or paused due to confusion about whose turn it was. Visual inspection of the data also identified 16 trials (0.55%) that contained intervals >2000 ms, which were excluded before calculating the mean ITIs. Excluding these trials also ensured that we examined people's experience of joint agency independent of attributions of blame for large timing errors. In total, 14.10% and 12.57% of trials were excluded from the high- and low-predictability conditions, respectively, leaving on average 25.77 and 26.23 agency ratings per participant in each condition.

2.4.2. Manipulation check

We calculated *confederate variability* (*SD* of the confederate's ITIs, from preceding tone to confederate tone) to confirm that, as per our manipulation, the high-predictability partner had less variable ITIs than the low-predictability partner ($M \pm SD$ = 5.51 ± 0.40 ms and 32.94 ± 1.97 ms, respectively), $t(47) = 95.90$, $p < 0.001$. *Participant variability* (*SD* of the participant's ITIs, from preceding tone to participant's tap) was also lower when participants coordinated with the high- than low-predictability partner ($M \pm SD$ = 26.75 ± 7.88 ms and 29.39 ± 8.02 ms), $t(47) = 3.24$, $p = 0.002$. Thus, participants engaged in the joint action by adapting their own action timing relative to their partner's. In addition, *confederate accuracy* (the absolute difference between the confederate's ITIs and the required 500 ms ITI) was higher (closer to the metronome pace) for the high- than low-predictability partner ($M \pm SD$ = 2.36 ± 0.37 ms and 13.71 ± 1.71 ms), $t(47) = 44.87$, $p < 0.001$. *Participant accuracy* (defined likewise) did not differ significantly between partners ($M \pm SD$ = 24.86 ± 14.14 ms and 27.83 ± 10.70 ms), $t(47) = 1.56$, $p = 0.13$.

2.4.3. Agency analysis

Agency data were analyzed using linear mixed-effects models so that we could control for covariates as described in the next paragraph. We first examined the effect of partner predictability on agency in the absence of covariates. We began with the maximal structure specified by our experimental design (Barr, Levy, Scheepers, & Tily, 2013): a fixed effect of predictability, a random intercept for participant, and a random slope for predictability at the participant level. To check whether the random effects could be reduced, we tested whether goodness of fit (−2 log-likelihood; −2LL) decreased significantly after removing the random effect that accounted for the least variance, using the likelihood ratio test (LRT; Bates, Kliegl, Vasishth, & Baayen, 2015). We then tested whether fit improved by including correlation parameters for the remaining variance components and the residuals (Bates et al., 2015). The final model (Model 1.1) included the random intercept and slope and heterogeneous residual covariances.

We next examined the effect of predictability after controlling for potential covariates. Because we expected the effect of predictability to be driven by our manipulation of confederate variability, we expected that (a) it would remain significant after controlling for participant and confederate accuracy and participant variability, and (b) it would be reduced after controlling for confederate variability. We used a step-up strategy (West, Welch, & Galecki, 2015) in which we added each covariate (followed, if significant, by its interaction with predictability) as fixed factors in the following order (Models 1.2–1.8): participant accuracy, confederate accuracy, participant variability, and confederate variability. To compare models with different fixed effects, we estimated model fit using full maximum likelihood and compared −2LLs using LRT. We re-estimated the effect of predictability after each covariate that significantly improved model fit, using restricted maximum likelihood. We report *F*-tests for fixed effects (degrees of freedom obtained by Satterthwaite approximation), as well as Cohen's *d* and standardized coefficients (β) as measures of effect size for categorical and continuous fixed effects, respectively.

3. Results

Fig. 2 shows participants' mean agency ratings by predictability as estimated in Model 1.1. As expected, participants rated their feelings of control as more shared when they coordinated with the high-predictability compared to low-predictability partner. Table 1 (left) shows the deviance for Model 1.1 and subsequent models. Table 1 (right) shows the effect of predictability (the difference in agency ratings between high- and low-predictability partners), along with its 95% CI, effect size, and *F*-test.

Table 1 (left) shows that adding participant accuracy, participant variability, and confederate variability significantly improved

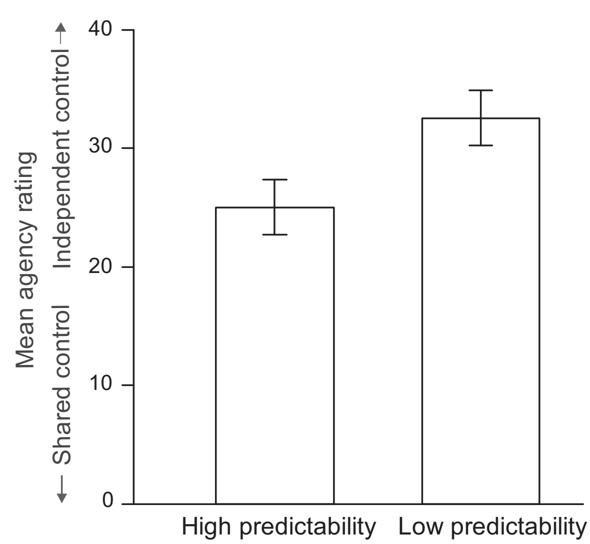

Fig. 2. Estimated mean agency ratings (±*SE*) by partner predictability.

Table 1
Model comparisons for the effects of participant and confederate accuracy and variability on agency ratings.

	Model comparisons				Effect of partner predictability			
	Δdf	−2LL	χ^2	p	Mean diff[a] [95% CI]	d	F (df)	p
Model 1.1		21337.43			−7.52 [−12.55, −2.50]	0.46	9.07 (1, 46.45)	0.004*
Model 1.2 [vs. 1.1]	1	21288.33	49.10	<0.001*	−7.08 [−12.01, −2.15]	0.43	8.34 (1, 46.48)	0.006*
Model 1.3 [vs. 1.2]	1	21285.14	3.19	0.07				
Model 1.4 [vs. 1.2]	1	21285.56	2.77	0.10				
Model 1.5 [vs. 1.2]	1	21205.79	82.54	<0.001*	−6.61 [−11.47, −1.75]	0.41	7.49 (1, 46.51)	0.009*
Model 1.6 [vs. 1.5]	1	21204.24	1.55	0.21				
Model 1.7 [vs. 1.5]	1	21201.58	4.21	0.04*	−4.18 [−9.53, 1.18]	0.26	2.42 (1, 71.58)	0.124
Model 1.8 [vs. 1.7]	1	21201.25	0.33	0.57				

Note. P = predictability; PA = participant accuracy; CA = confederate accuracy; PV = participant variability; CV = confederate variability.
Model 1.1 = P.
Model 1.2 = P + PA.
Model 1.3 = P + PA + P * PA.
Model 1.4 = P + PA + CA.
Model 1.5 = P + PA + PV.
Model 1.6 = P + PA + PV + P * PV.
Model 1.7 = P + PA + PV + CV.
Model 1.8 = P + PA + PV + CV + P * CV.
* $p < 0.05$.
[a] Mean difference = high-predictability partner minus low-predictability partner.

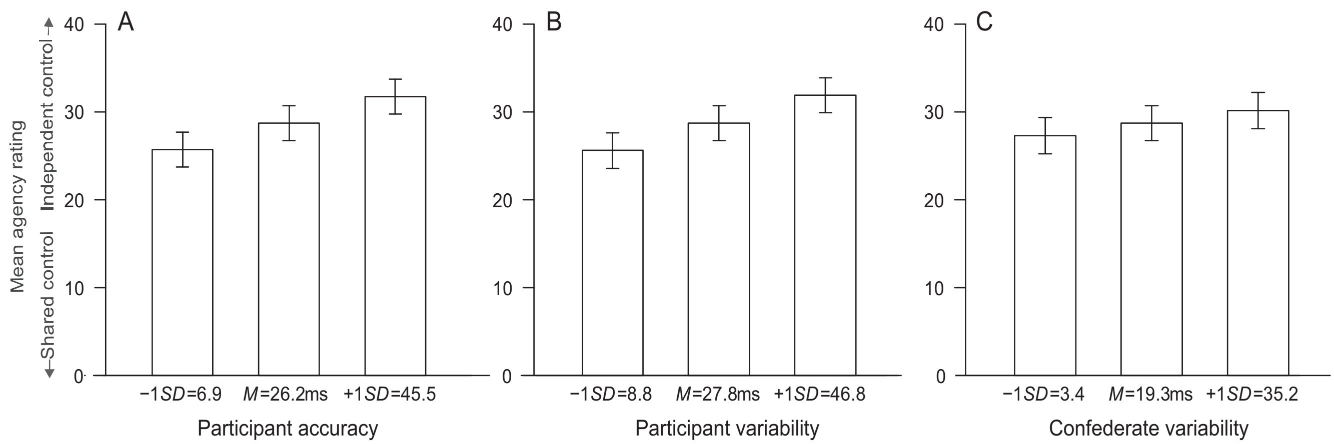

Fig. 3. Estimated mean agency ratings (±*SE*) plotted at mean ± 1*SD* values of (A) participant accuracy, (B) participant variability, and (C) confederate variability.

model fit, whereas adding confederate accuracy and interactions between each covariate and predictability did not. Table 1 (right) shows that, as expected, the effect of predictability was approximately the same size (and significant) after participant accuracy and variability were included in the model (Models 1.2 and 1.5), but was smaller in size (and non-significant) when confederate variability was included in the model (Model 1.7).[3]

Fig. 3 shows the effects of participant accuracy, participant variability, and confederate variability on agency ratings as estimated in Model 1.7. Participants rated their feelings of control as more shared when their own ITIs were more accurate (Fig. 3A), $b = 0.16$, $F(1,2455.93) = 55.50$, $p < 0.001$, $\beta = 0.13$, and less variable (Fig. 3B), $b = 0.17$, $F(1,2359.86) = 81.92$, $p < 0.001$, $\beta = 0.14$, on a given sequence. Participants also rated their feelings of control as more shared when their partner's ITIs were less variable (Fig. 3C), $b = 0.09$, $F(1,1301.35) = 4.20$, $p = 0.041$, $\beta = 0.07$.

4. Discussion

We examined whether the predictability of a partner's actions influences the experience of joint agency. Participants coordinated their actions with confederates whose action timing was manipulated to be more or less predictable. People reported stronger feelings of shared (as opposed to independent[4]) control when they coordinated with the more predictable partner. This difference remained after statistically controlling for effects of the accuracy and variability of the participant's action timing on joint agency,

[3] The effect of predictability was also reduced and non-significant when *only* confederate variability was added to Model 1.1 (mean difference = −4.26 [−9.78, 1.27], $d = 0.18$, $F(1,71.08) = 2.36$, $p = 0.13$). Furthermore, the effects of accuracy were the same (i.e., participant accuracy improved model fit but confederate accuracy did not) when participant and confederate accuracy were added in reverse order. Finally, we note here that in an initial covariate analysis we included accuracy measured at the pair level (i.e., the absolute difference between the mean ITI for a given trial and the required 500 ms) rather than separately for participant and confederate. Consistent with previous research showing effects of pair-level accuracy on agency during joint action, adding pair-level accuracy to Model 1.1 significantly improved model fit (−2LL = 21304.21, $\chi^2(1) = 33.22$, $p < 0.001$) and participants rated their feelings of control as more shared when the joint performance was more accurate, $b = 0.25$, $F(1,2457.44) = 41.75$, $p < 0.001$, $\beta = 0.11$. An anonymous reviewer pointed out that the effect of pair-level accuracy could be driven primarily by participant accuracy, which modeling them separately confirmed, as reported in the main text. We thank the reviewer for this suggestion.

[4] Our rating scale measured the *type* of agency people experienced (i.e., shared vs. independent control) but not the *degree* of agency people experienced (e.g., more vs. less control), which may vary independently (Pacherie, 2012). We therefore discuss agency type (i.e., the strength of joint relative to independent agency) and draw no conclusions about agency degree.

but was no longer significant after controlling for the variability of the partner's action timing. These findings confirm that partner predictability influenced joint agency independently of a person's own action timing.

The current findings provide direct evidence for Pacherie's (2012) hypothesis that more accurate predictions about a co-performer's actions lead to stronger feelings of joint agency. Thus, not only do people make predictions about others' actions and incorporate them into their action planning during joint action (Knoblich & Jordan, 2003; Kourtis et al., 2013; Loehr et al., 2013; Vesper, van der Wel, Knoblich, & Sebanz, 2013), they also rely on those predictions to inform their sense of joint agency. The association between higher predictability on a given trial (i.e., less variability in the partner's timing) and stronger joint agency has implications for research showing that people reduce the variability of their actions to improve interpersonal coordination (Vesper, Schmitz, Safra, Sebanz, & Knoblich, 2016; Vesper, van der Wel, Knoblich, & Sebanz, 2011). The current findings suggest that such "coordination smoother" strategies (Vesper et al., 2010) might have the added benefit of strengthening joint agency, which may in turn enhance interpersonal affiliation or group cohesion (Carron, Shapcott, & Burke, 2007; Overy & Molnar-Szakacs, 2009).

The current study revealed two additional findings. First, in addition to the effect of partner predictability, people experienced stronger joint agency when their own action timing was more accurate and less variable. Consistent with previous research showing that characteristics of both one's own and a partner's movements influence feelings of control during joint action (van der Wel, 2015), we show here that information about both one's own and a partner's actions specifically influences *joint* agency. Second, people's own accuracy had a stronger influence on joint agency than did their partner's accuracy. Whereas previous research examined the influence of pair-level accuracy on agency during joint action (Dewey et al., 2014; van der Wel et al., 2012), the task used here allowed each partner's accuracy to be measured separately. Our findings reveal that partners' contributions to pair-level accuracy may be weighted differently when deriving a sense of joint agency.

In sum, the current study shows that people experience stronger joint agency when they are better able to predict the timing of their partner's actions. Thus, congruence between predicted and actual consequences of another person's actions influences the sense of joint agency, much like congruence between predicted and actual consequences of one's own actions influences the sense of self-agency. These findings provide empirical support for the theoretical prediction that joint agency is driven in part by predictions about co-performers' actions. Interesting questions for future research include what characteristics of a joint action determine how other-predictions are weighted relative to self- and joint-predictions and by what mechanisms they are integrated into a coherent experience of joint agency.

Acknowledgments

This research was supported by the University of Saskatchewan and the Natural Sciences and Engineering Research Council of Canada [Canada Graduate Scholarship and grant number 2108299]. The authors thank Lauren Slavik and Bethan Weeding for assistance with data collection.

Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.cognition.2017.01.004.

References

Bargh, J. A., & Chartrand, T. L. (2000). A practical guide to priming and automaticity research. In H. Reis & C. Judd (Eds.), *Handbook of research methods in social psychology* (pp. 253–285). Cambridge, UK: Cambridge University Press.

Barr, D. J., Levy, R., Scheepers, C., & Tily, H. J. (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of Memory and Language, 68*, 255–278.

Bates, D., Kliegl, R., Vasishth, S., & Baayen, H. (2015). *Parsimonious mixed models*. Available from arXiv preprint 1506.04967.

Bolt, N. K., Poncelet, E. M., Schultz, B. G., & Loehr, J. D. (2016). Mutual coordination strengthens the sense of joint agency in cooperative joint action. *Consciousness and Cognition, 46*, 173–187.

Carron, A. V., Shapcott, K. M., & Burke, S. M. (2007). Group cohesion in sport and exercise. In M. R. Beauchamp & M. A. Eys (Eds.), *Group dynamics in exercise and sport psychology* (pp. 117–139). New York, NY: Routledge.

Dewey, J. A., Pacherie, E., & Knoblich, G. (2014). The phenomenology of controlling a moving object with another person. *Cognition, 132*, 383–397.

Dokic, J. (2010). Affordances and the sense of joint agency. In M. Balconi (Ed.), *Neuropsychology of the sense of agency* (pp. 23–43). Milan, Italy: Springer.

Frith, C., Blakemore, S., & Wolpert, D. (2000). Abnormalities in the awareness and control of action. *Philosophical Transactions of the Royal Society of London B, 355*, 1771–1788.

Haggard, P., & Eitam, B. (2015). Introduction. In P. Haggard & B. Eitam (Eds.), *The sense of agency* (pp. xi–xvi). Oxford, England: Oxford University Press.

Haggard, P., & Tsakiris, M. (2009). The experience of agency: Feelings, judgments, and responsibility. *Current Directions in Psychological Science, 18*, 242–246.

Keller, P. E., Knoblich, G., & Repp, B. H. (2007). Pianists duet better when they play with themselves: On the possible role of action simulation in synchronization. *Consciousness and Cognition, 16*, 102–111.

Keller, P. E., Novembre, G., & Loehr, J. D. (2016). Musical ensemble performance: Representing self, other, and joint action outcomes. In S. Obhi & E. Cross (Eds.), *Shared representations: Sensorimotor foundations of social life* (pp. 280–311). Cambridge, UK: Cambridge University Press.

Knoblich, G., & Jordan, J. S. (2003). Action coordination in groups and individuals: Learning anticipatory control. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 29*, 1006–1016.

Kourtis, D., Sebanz, N., & Knoblich, G. (2013). Predictive representation of other people's actions in joint action planning: An EEG study. *Social Neuroscience, 8*, 31–42.

Loehr, J. D., Kourtis, D., Vesper, C., Sebanz, N., & Knoblich, G. (2013). Monitoring individual and joint action outcomes in duet music performance. *Journal of Cognitive Neuroscience, 25*, 1049–1061.

Loehr, J. D., & Palmer, C. (2011). Temporal coordination between performing musicians. *Quarterly Journal of Experimental Psychology, 64*, 2153–2167.

Moore, J. W., & Fletcher, P. C. (2012). Sense of agency in health and disease: A review of cue integration approaches. *Consciousness and Cognition, 21*, 59–68.

Overy, K., & Molnar-Szakacs, I. (2009). Being together in time: Musical experience and the mirror neuron system. *Music Perception, 26*, 489–504.

Pacherie, E. (2008). The phenomenology of action: A conceptual framework. *Cognition, 107*, 179–217.

Pacherie, E. (2012). The phenomenology of joint action: Self-agency vs. joint-agency. In A. Seemann (Ed.), *Joint attention: New developments* (pp. 343–389). Cambridge, MA: MIT Press.

Peirce, J. W. (2007). PsychoPy – Psychophysics software in Python. *Journal of Neuroscience Methods, 162*, 8–13.

Sato, A., & Yasuda, A. (2005). Illusion of sense of self-agency: Discrepancy between the predicted and actual sensory consequences of actions modulates the sense of self-agency, but not the sense of self-ownership. *Cognition, 94*, 241–255.

Schultz, B. G., & van Vugt, F. T. (2015). Tap Arduino: An Arduino microcontroller for low-latency auditory feedback in sensorimotor synchronization experiments. *Behavioral Research Methods*, 1–17.

Sebanz, N., Bekkering, H., & Knoblich, G. (2006). Joint action: Bodies and minds moving together. *Trends in Cognitive Sciences, 10*, 70–76.

Seemann, A. (2009). Joint agency: Intersubjectivity, sense of control, and the feeling of trust. *Inquiry: An Interdisciplinary Journal of Philosophy, 52*, 500–515.

Synofzik, M., Vosgerau, G., & Voss, M. (2013). The experience of agency: An interplay between prediction and postdiction. *Frontiers in Psychology, 17*, 78–85.

van der Wel, R. P. R. D. (2015). Me and we: Metacognition and performance evaluation of joint actions. *Cognition, 140*, 49–59.

van der Wel, R. P. R. D., & Knoblich, G. (2013). Cues to agency: Time can tell. In J. Metcalfe & H. Terrace (Eds.), *Agency and joint attention* (pp. 256–267). New York, NY: Oxford University Press.

van der Wel, R. P. R. D., Sebanz, N., & Knoblich, G. (2012). The sense of agency during skill learning in individuals and dyads. *Consciousness and Cognition, 21*, 1267–1279.

Vesper, C., Butterfill, S., Knoblich, G., & Sebanz, N. (2010). A minimal architecture for joint action. *Neural Networks, 23*, 998–1003.

Vesper, C., Knoblich, G., & Sebanz, N. (2014). Our actions in my mind: Motor imagery of joint action. *Neuropsychologia, 55*, 115–121.

Vesper, C., Schmitz, L., Safra, L., Sebanz, N., & Knoblich, G. (2016). The role of shared visual information for joint action coordination. *Cognition, 153*, 118–123.

Vesper, C., van der Wel, R. P. R. D., Knoblich, G., & Sebanz, N. (2011). Making oneself predictable: Reduced temporal variability facilitates joint action coordination. *Experimental Brain Research, 211*, 517–530.

Vesper, C., van der Wel, R. P. R. D., Knoblich, G., & Sebanz, N. (2013). Are you ready to jump? Predictive mechanisms in interpersonal coordination. *Journal of Experimental Psychology: Human Perception and Performance, 39*, 48–61.

West, B. T., Welch, K. B., & Galecki, A. T. (2015). *Linear mixed models: A practical guide using statistical software* (2nd ed.). Boca Raton, FL: CRC Press.

Wolpert, D. M., Doya, K., & Kawato, M. (2003). A unifying computational framework for motor control and social interaction. *Philosophical Transactions of the Royal Society of London B, 358*, 593–602.