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Journal

Proceedings of the Annual Meeting of the Cognitive Science Society, 44(44)

Authors

Kodama, Kentaro
Shimizu, Daichi
Fujiwara, Ken

Publication Date

2022

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Kentaro Kodama (kodama_k@tmu.ac.jp)
University Education Center, Tokyo Metropolitan University
1-1 Minami-Osawa, Hachioji-shi, Tokyo, 192-0397, Japan

Daichi Shimizu (d-shimizu@people.kobe-u.ac.jp)
Graduate School of Human Development and Environment, Kobe University
3-11 Tsurukabuto, Kobe-shi, Hyogo, 657-0011, Japan

Ken Fujiwara (psykf@ccu.edu.tw)
Department of Psychology, National Chung Cheng University
No.168, Sec. 1, University Rd., Minhsiung, Chiayi 621301, Taiwan (R.O.C.)

Abstract

We investigated the influence of visual information on interpersonal coordination of head- and body- movement during dyadic conversations. Visual information was manipulated by locating a partition at a halfway point between participants. Interpersonal coordination dynamics between head- and body- movement was also compared. To quantify the amount of such movement, human pose estimation software was used. The time series of each body part were submitted to the cross-recurrence quantification analysis to assess the degree of coordination. We hypothesized that unavailability of visual information increase interpersonal bodily coordination and experimental manipulation affects interpersonal coordination during conversation but does differently between head- and body- movement levels. As predicted, results revealed that occlusion of visual information increased head-movement coordination between participants while no significant difference was found in body-movement coordination between conditions. Further investigations on the mechanism of such different influences of perceptual information on coordination dynamics at multiple levels should be pursued.

Keywords: interpersonal coordination; perceptual coupling; visual information; nonlinear time series analysis

Introduction

Interpersonal coordination

In recent decades, interpersonal coordination or synchrony has received significant attention in cognitive science (Bernieri & Rosenthal, 1991; Dale et al., 2013; Keller et al., 2014; Riley et al., 2011). It has been investigated across a wide continuum, from perceptual-motor *low-level* process (e.g., Schmidt et al., 2011; Tognoli et al., 2007) to cognitive-social *high-level* process (e.g., Garrod & Pickering, 2009; Paxton & Dale, 2013).

Interpersonal bodily coordination such as postural and head-movement coordination can change depending on linguistic factors (Shockley et al., 2007), communication type (Paxton & Dale, 2013), and social relationships (Fujiwara et al., 2020) during verbal communication. It is also supposed to affect socio-psychological factors such as affiliation and likability (Hove & Risen, 2009). However, research on low-level constraints on interpersonal coordination such as perceptual information is limited (Paxton & Dale, 2017).

Effect of perceptual information and noise

It is known that our movements are coordinated with those of others during conversation even without visual information (Shockley et al., 2003). In other words, interpersonal coordination can emerge through verbal interaction using only auditory information. A previous study found a significant increase in interpersonal coordination (e.g., head-movement coordination) between participants when the auditory noise was present (Boker et al., 2002). They interpreted that participants more closely coupled their movements to each other when verbal communication became more difficult. Recently, greater synchrony (i.e., movement coherence) in more difficult communication conditions in terms of background noise has also been reported (Hadley & Ward, 2021). These studies revealed that auditory information as background noise can affect and enhance interpersonal coordination among participants. In addition to such information, visual information as noise is assumed to increase interpersonal coordination (Paxton & Dale, 2017). Paxton and Dale (2017) manipulated visual stimuli by asking participants to wear special glasses and adapting flashing screens on the glass. As they hypothesized that changing visual information interpreted as noise will increase head-movement coordination, it partially increased depending on the conversational context. These findings suggest that perceptual information enables us to coordinate our body movements with others. They also indicate that perceptual noise, which makes communication more difficult, may enhance our bodily coordination.

Distinct mechanisms of head- and body-synchrony

Ramseyer and Tschacher (2014) investigated interpersonal synchrony between patient's and therapist in psychotherapy. They quantified head- and body-synchrony and assessed both

In J. Culbertson, A. Perfors, H. Rabagliati & V. Ramenzoni (Eds.), *Proceedings of the 44th Annual Conference of the Cognitive Science Society.*

micro-outcomes with self-report post-session questionnaires and macro-outcomes via questionnaires that quantified attainment of treatment goals and changes in experience and behavior at the end of therapy (Ramseyer & Tschacher, 2014). Their results indicated that head-synchrony predicted the global outcome of therapy, and body-synchrony predicted session outcome. They argued that the separation of head- and body-synchrony suggested that distinct mechanisms may operate in these two regions: head-synchrony embodied phenomena with along temporal extension (overall therapy success), while body-synchrony embodied phenomena of a more immediate nature (session-level success) (Ramseyer & Tschacher, 2014).

Aims and hypothesis

We examined the influence of visual information on interpersonal coordination of head- and body-movement during dyad conversations. Previous studies on the influence of perceptual information and noise suggested that interpersonal coordination may serve to boost the communication signal within the noisy environment (Paxton & Dale, 2017). Accordingly, we hypothesized that unavailability of visual information may increase interpersonal bodily coordination. Other previous research has posited that there is a distinct mechanism of head- and body-synchrony (Ramseyer & Tschacher, 2014). Thus, we also expected that differing dynamics can be observed between head- and body-movement coordination.

Method

Participants

A total of 52 pairs of participants (17 female pairs, aged (mean ± SD) 20.06 ± 1.15 years, all native Japanese speakers) were recruited. The experimental procedures were approved by the research ethics committee in the Faculty of Human Sciences at Osaka University of Economics, where the experiment was conducted. Each participant provided written informed consent agreeing to participate in this study.

Apparatus

A video camera (HDR-PJ800, SONY) was placed in front of participants at a distance of 280 cm and used to record participants' body movements (frame rate was 30 FPS). MATLAB (R2020b, MathWorks) and RStudio (1.4.1103) were used to analyze the data.

Figure 1: Experimental situation
(left: visible condition, right: invisible condition)

Procedure

In the current experiment, two conditions were compared: the visible condition (both visual and auditory information were available, just as in a natural situation shown in Figure 1 left) and the invisible condition (only auditory information was available since a partition was located at the halfway point between two participants) (i.e., within-subjects design). Participants were instructed to have 6-minute conversations to get to know each other better. Since the conversation topics were not specified, most participants talked about each other's recent activities. The pairs conducted each condition and the order of two conditions was counterbalanced across pairs of participants.

Data analysis

To quantify how much each participant moved, an automated objective video-analysis algorithm was performed in Ubuntu 18.04 on a laptop computer (XPS7390, DELL) with OpenPose v1.5.1 (Cao et al., 2017). It estimates 2D coordinate information about joint body parts. A total of 15 coordinate points (i.e., nose, eyes, neck, shoulders, elbows, wrists, left and right hip, mid-hip, and knees) were used for analysis, whereas ankles were not included because they were frequently out of the frame. To compensate for the missing values of the coordinates, linear interpolation using the filloutliers function of MATLAB. To obtain the movement time series, the distance of each coordinate between frames was calculated using Pythagoras theorem. The distances of nose and eyes were summed for the head movement, and the other 12 distances were summed to represent body movement, which was applied throughout the conversation.

To quantify the degree of interpersonal coordination between participants, a nonlinear time series analysis, called the *cross-recurrence quantification analysis* (CRQA), was applied between two time series of head- and body- movement of each participant (Figure 1). CRQA is a nonlinear time series analysis method that captures the recurring properties and patterns of a dynamical system, resulting from two streams of information interacting over time (Zbilut et al., 1998). RQA was originally developed to uncover subtle time correlations and repetitions of patterns, and it is relatively free of assumptions about data size and distribution (Zbilut & Webber, 1992). In CRQA, two time-delayed copies of the original time series are used to embed the data in a higher dimensional space to analyze the recurrent structure between them (Zbilut et al., 1998).

This study calculated two CRQA measures, namely, the *percentage of recurrence* (%REC) and *max line length* (MAXL). For interpersonal coordination, %REC in CRQA corresponds to the ratio of the actual number of shared locations and the number of possible shared locations in the phase space (Shockley, 2005). This means that a higher %REC indicates less noise in the system, in other words, the system is more stable. The other measure was related to the line structure calculated from the recurrence plot, MAXL. It is the longest shared trajectory in phase space and the length of the maximum diagonal line on the plot

(Webber & Zbilut, 2005). MAXL is a measure of the stability of the shared activity (Shockley, 2005). It is supposed to provide an index of the system's sensitivity to perturbations (i.e., the strength of the attractor against perturbations) (Pellecchia et al., 2005).

After determining the optimal values for input parameters with reference to the standard guidelines for the RQA method (Webber & Zbilut, 2005), we performed CRQA using the MATLAB toolbox CROSS-RECURRENCE PLOT TOOLBOX (version 5.21) (Marwan & Kurths, 2002) and the R package "crqa" (version 2.0.2) (Coco & Dale, 2014). As a result, we chose parameters of 30 for time delay, 7 for embedding dimensions, and 0.6 for the radius within Euclidean norm between normalized vectors. For statistical comparisons, the Mann–Whitney U test, which is a non-parametric test, was conducted since our data did not exhibit normal distributions.

Results

Head-movement coordination

%REC of head-movement coordination between participants is illustrated in Figure 2. %REC was 2.33% (SD = 0.79). and 3.13% (SD = 1.50) in the visible and invisible conditions, respectively. The %REC was significantly higher in the latter than in the former (*p* =.002 and *r* =.419; *p*-value and effect size *r*, respectively).

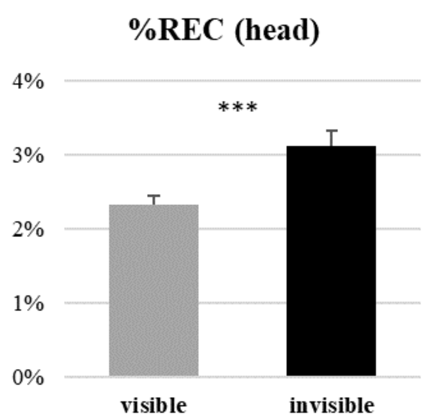

Figure 2: %REC of head-movement coordination
Left: visible condition, Right: invisible condition
(error bar: standard deviation, *** *p*<0.005)

MAXL of head-movement coordination between participants is illustrated in Figure 3. MAXL was 65.85 (SD = 59.71) and 95.90 (SD = 70.98) in the visible and invisible conditions, respectively. The MAXL was significantly higher in the latter than in the former (*p* =.009 and *r* =.342).

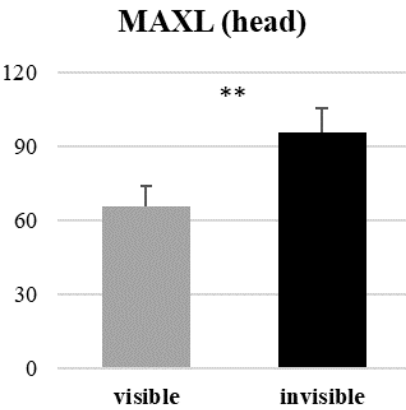

Figure 3: MAXL of head-movement coordination
Left: visible condition, Right: invisible condition
(error bar: standard deviation, ** *p*<0.01)

Body-movement coordination

%REC of body-movement coordination between participants is illustrated in Figure 4. %REC was 5.36% (SD = 3.53) and 3.13% (SD = 5.73) in the visible and invisible conditions, respectively. There was no significant difference in the %REC between the two conditions (*p* =.689 and *r* =.056).

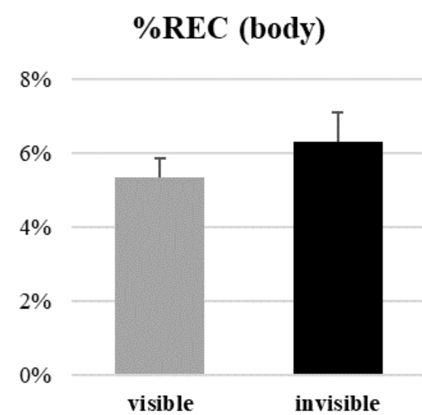

Figure 4: %REC of body-movement coordination
Left: visible condition, Right: invisible condition
(error bar: standard deviation)

MAXL of body-movement coordination between participants is illustrated in Figure 5. MAXL was 278.00 (SD = 135.40) and 272.15 (SD = 185.53) in the visible and invisible conditions, respectively. There was no significant difference in the MAXL between the two conditions (*p* =.552 and *r* =.083).

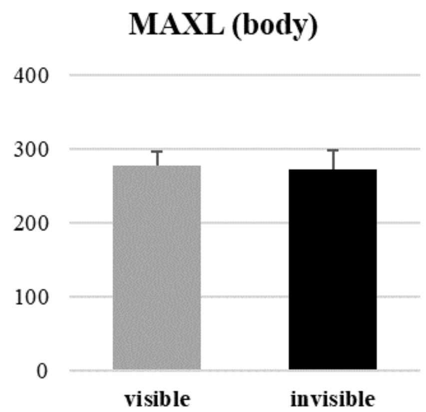

Figure 5: MAXL of body-movement coordination
Left: visible condition, Right: invisible condition
(error bar: standard deviation)

Discussion

Head-movement coordination

The %REC and MAXL of head-movement coordination were higher in the invisible condition than in the visible condition. This indicates that the participants were able to coordinate their head-movement with each other more stably without visual information than with visual information. As suggested by a previous study (Paxton & Dale, 2017), occlusion of visual information increased interpersonal coordination at head-movement level in dyads. This result supports our hypothesis.

Body-movement coordination

Contrary to head-movement coordination, the %REC and MAXL of body-movement coordination did not differ between two conditions. This result indicates that the participants were able to coordinate stably regardless of the availability of visual information since overall values of %REC of body-movement coordination were higher than that of head- movement coordination. As reported in a previous study (Shockley et al., 2003), participants in the current study were able to coordinate their bodies with each other using only auditory information during verbal communication.

General discussion

It is interesting that occlusion of visual information affected head- and body- movement coordination differently. At the head-movement level, the invisible condition may enhance or boost the communication signal as predicted based on previous studies (Paxton & Dale, 2017). At body-movement level, interpersonal coordination did not differ regardless of availability of visual information. Why was such a different result obtained from two levels of interpersonal coordination?

Previous research argued that distinct mechanisms may operate at these two levels (Ramseyer & Tschacher, 2014). Head-movement coordination embodied phenomena with along temporal extension at longer term scale, while body-movement coordination embodied phenomena of a more immediate nature at the shorter term scale (Ramseyer & Tschacher, 2014). From the viewpoint of these distinct mechanisms, we can interpret our results as visual information during conversation may affect long-term phenomena reflected in head-movement coordination. However, we have not examined long-term phenomena such as change of social relationship, process of building rapport, and so on. Further examination of the correlation between these long-term phenomena and bodily coordination should be conducted.

It is also possible to suppose that relationship between bodily coordination (i.e., head- or body-movement level) and embodied social and cognitive phenomena (e.g., long- or short- term aspect) can change depending on communication type and available perceptual information. In psychotherapy, head-movement (i.e., nodding) has an important role for therapists to display their understanding, alignment, and empathy to clients (Graf et al., 2014; Muntigl et al., 2012). This nonverbal behavior can be used as a clinical technique in psychotherapy and may lead to building rapport between them and have a long-term influence on therapist-client relationship. Thus, head-movement coordination (i.e., nodding) can relate to long-term aspects in a specific communication type such as psychotherapy.

By contrast, in natural conversation, head-movement (i.e., nodding) does not always have the same function as in psychotherapy as nodding has various functions (McClave, 2000). Particularly when participants have already built social relationships as friends as in this experiment, they may not intend to display their understanding, alignment, and empathy. In addition, when participants cannot see each other (i.e., the invisible condition), nodding may have different function such as boosting the communication signal through auditory information (Paxton & Dale, 2017), then head-movement coordination can increase. In such a case, interpersonal coordination can be organized through perceptual coupling via auditory information (Shockley et al., 2003) that can be regarded as fast-changing phenomena on a short-term scale (Dale, 2015). Thus, head-movement coordination may not always embody long-term/slow-changing phenomena.

Our results reveal a possibility that there may be a distinct mechanism at the head- and body-movement coordination level. In addition, we speculate that the relationship between coordination dynamics at each level (i.e., head or body) and embodied social and cognitive phenomena (e.g., long- or short- term aspect) may change depending on communication type and available perceptual information. Further investigation should be conducted to clarify this notion.

Conclusion

We investigated the influence of visual information on interpersonal coordination of head- and body-movement during dyad conversations. We also compared different dynamics between head- and body-movement coordination. Results indicated that occlusion of visual information increased head-movement coordination between participants while no significant difference was found in body-movement coordination between conditions. Further investigations on the mechanism of such different influences of perceptual information on coordination dynamics at multiple levels should be pursued in the future.

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