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Mutual Gaze Facilitates Synchronization during Piano Duo Performances

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ABSTRACT

This study investigated the roles of gazing behaviour (specifically eye contact) during music performances by focusing on coordination among performers. Experiment 1 was conducted under four different visual-contact conditions: invisible, only the body visible, only the head visible, and face-to-face. Experiment 2 was conducted under three different visual-contact conditions: invisible, only the movable-head visible, and only the fixed-head visible; the condition was implemented by using a chin rest. The results of experiment 1 showed that the timing lag between performers did not vary significantly among the three conditions in which visual cues were available. Performers looked toward each other just before changes of tempo during which two performers need to coordinate timing in both experiments. Under these three conditions, when performers looked toward each other at points of coordination, it significantly improved synchronization accuracy. The results of experiment 2 showed that the timing lag was significantly shorter under the fixed-head condition than the invisible condition, and significantly longer under the fixed-head condition than the movable-head condition. Regardless of whether or not the head was fixed, the timing lag decreased when performers made eye contact just before the beginning of the sound. On the basis of two experiments, we conclude that mutual gaze is important for reducing timing lag during a performance and that performers may utilize movements (body or head) as visual cues for coordination since they can coordinate only loosely through eye contact alone (without movement).

I. INTRODUCTION

What types of cues do musicians utilize to create a live artistic ensemble performance? In ensemble performance, musicians need to cooperate and communicate with co-performers. To elucidate the synthetic communication process during ensemble performance, it is necessary to analyse behaviours occurring among performers and reveal their roles in performance.

Ensemble musicians need to communicate with both co-performers and audiences during performance. Studies on the relationship between musical performance and visual information have investigated the encoding of performers' intentions and their decoding by listeners. These studies have shown that performers' body movements or facial expressions contribute to listeners' comprehension of their performance (e.g. Davidson, 1993; Davidson, 1994; Thompson, Graham, & Russo, 2005). However, few studies have examined the role of visual information in inter-performer communication.

On an empirical level, it seems difficult for musicians to play without the visual cues of co-performers. Indeed, various inter-performer non-verbal behaviours have been observed during ensemble performance. Luck and Toiviainen (2006) revealed that the sounds made by performers were synchronized with the body movements of their conductor. Maduell and Wing (2007) examined the social relationships between flamenco performers and conducted an analysis of behaviour during performance. Goebl and Palmer (2009) indicated that pianists' body movements increased in synchronization as auditory feedback was reduced. Fredrickson (1994) showed that listeners highly evaluated the performance when performers played using both visual and sound cues. These studies suggested that visual communication among performers contributes to acoustically or subjectively better performance.

With respect to the communication channels utilized by performers, channels other than body movements have hardly been investigated, although many types of non-verbal communication (e.g. facial expression, gazing, posture, proxemics, etc.) are used in everyday interpersonal communication. To determine the integrative process and mechanism of ensemble performance, it is necessary to reveal the roles and functions of other channels of communication. Therefore, we focused on gazing (eye direction).

Gazing behaviours have proven empirical importance in everyday interpersonal communication (e.g., Kendon, 1967; Baron-Cohen, 1995). In ensemble performances, Fredrickson (1994) analysed for how long performers looked at a videotaped conductor, finding that they looked at the conductor for 28% of the duration of performance. Moran (2010) showed that musicians' looking behaviours occurred with fairly consistent durations of one to four seconds. Williamon and Davidson (2002) examined the duration of eye contact in piano duo performance and suggested that it increased with each performance. Additionally, Davidson (2005) revealed that performers in a popular music band frequently made eye contact. These prior studies indicated that gazing may contribute to the facilitation of ensemble performance in some way (i.e. technically, emotionally, or socially). Furthermore, the quantitative gazing data of ensemble performers will be useful not only to understand the role of gazing itself but also to reveal at what performers look, and when, during performance.

This study investigated the relationship between gazing behaviour and timing coordination (which is the most elemental requirement of ensemble performance). This enabled deeper analysis of the nonverbal behaviour mechanisms at play in ensemble performance.

II. EXPERIMENT 1

A. Aim

The purpose of experiment 1 was to explore whether or not the cue of gazing is necessary for coordination. We measured gazing behaviour when a performer looked at a co-performer during a piano duo performance under four visual contact conditions. We also examined the relationship between gazing behaviour and timing lag in musical sound.

B. Method

1) Participants. Six pianists (6 female; age range = 20–31 years; mean age = 25.8 years; mean performance experience = 21.8 years) participated in the experiment. They were professional pianists or recommended by a lecturer at a music school. None of the pianists reported regular experience with piano duos.

2) Materials. We used ‘Prologue de Coq’licot’, the first in a series of four pieces titled *Quatre Tableaux Féeriques* (composed by Yumiko Kano). The piece incorporates nine changes of tempo, during which the two performers need to coordinate timing and begin to play simultaneously after a long pause.

3) Procedure. Each performer was located and played in a separate soundproof room. The performers made visual contact through a glass window. The participants each played an electric piano (P-155, Yamaha). The sound was recorded on a multitrack recorder (SX-1, TEAC). The participants played the tune thrice under each of four different visual-contact conditions ordered as follows: (1) partner-invisible; (2, 3) able to see only the body, able to see only the head (ordered randomly for each pair); and (4) face-to-face (Figure 1).

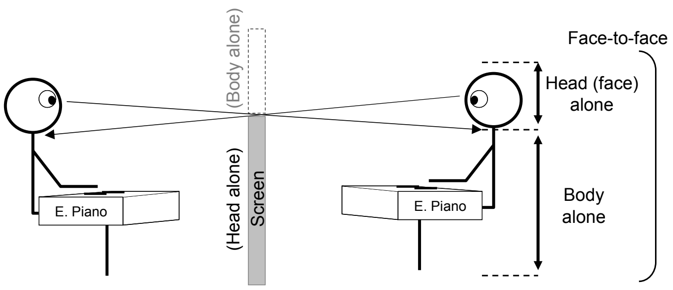

Figure 1. Visual-contact conditions.

4) Measurements. We recorded the performance on four video cameras and analysed each performer’s gaze frame-by-frame using the Behaviour Coding System software package (IFS-18C, DKH). The temporal resolution of the video was 29.97 frames per second. We employed the observational method of Argyle (1999) in order to obtain the data without disturbing the players’ performance. We analysed the sound produced by each performer (recorded in separate tracks). Timing lag between performers was measured using the Sound Forge software package (Sony Pictures Digital Inc.) with reference to the waveform. The experimenter and a collaborator measured the same 54 samples; the average difference in timing was 0.37 msec and the standard deviation was 0.81 msec.

C. Results

The average values of timing lag between the performers at nine tempo change points under each visual contact condition are presented in Figure 2. The average values of timing lag were 168, 62, 55, and 47 msec under partner-invisible condition, body-visible condition, head-visible, and face-to-face conditions, respectively. The results of an analysis of variance (ANOVA) on timing lag showed significant differences between each condition (F (1.697, 135.760) = 28.409, $p < 0.001$). Multiple comparisons revealed significant differences between the partner-invisible condition and the other conditions (Bonferroni’s method, $p < 0.01$).

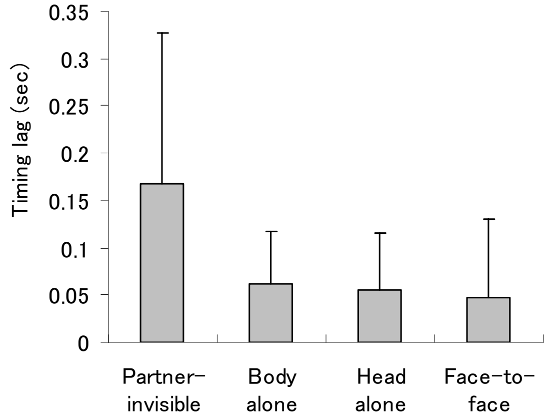

Figure 2. The average value of timing lag under each visual contact condition: partner-invisible, body alone, head alone, and face-to-face.

The frequency of a performer’s gaze toward the co-performer under each condition was the highest around the times when the tempo changed. Figure 3 indicates gazing behaviour under each condition during tempo changes, when performers had to synchronize. Zero seconds on the horizontal axis represents the starting time of the performance sound. Negative values indicate that the performer looked toward the co-performer before the starting point of performance. This figure depicts the average data of 162 samples (six participants × three trials × nine points of tempo change). The vertical axis represents the frequency of gazing behaviour at all points of tempo change. The results showed that the frequencies of both a performer’s gaze toward the co-performer and their eye contact under each condition were highest just before points of tempo change.

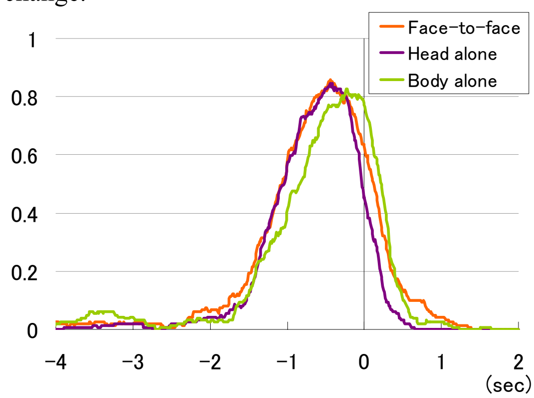

Figure 3. Gazing behaviour at the points of tempo change. Zero seconds in the horizontal axis represents the starting time of performance sound. The vertical axis represents the frequency of gazing behaviour at all points of tempo change.

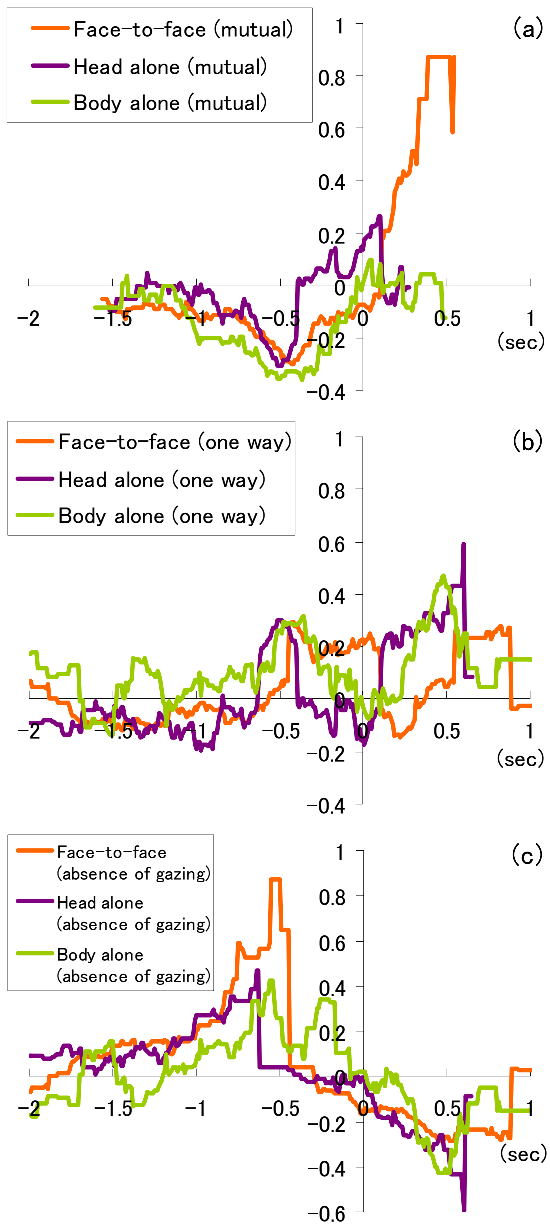

Figure 4. The correlation coefficient between the timing lag and gaze at each time point. The horizontal axis represents the time of performance sound (zero means starting time of performance sound). The vertical axis represents the point-biserial correlation coefficient between timing lag and gazing behaviour at each point of tempo change. Each figure represents the results of (a) mutual gazing, (b) one way gazing and (c) absence of gazing under each condition.

Next, we analysed the influence of gazing behaviour on timing coordination. We coded performers' gazing behaviour as eye contact, one-way gazing, or absence of gazing; the coding scheme was binarized (occurrence [1] or non-occurrence [0]). We calculated the point-biserial correlation coefficient between timing lag and gazing behaviour at each point of tempo change (Figure 4). The results showed that the correlation coefficient of eye contact (mutual gazing) and timing lag was significantly low just before the points of tempo change under all conditions. The minimum values of the point-biserial correlation coefficient were -0.30 (t = -0.43 and -0.42, p = 0.007; t represents time) under the face-to-face condition, -0.36 (t = -0.37, p = 0.001) under the body alone condition, and -0.30 (t = from -0.51–-0.49, p = 0.006) under the head-alone condition. At the same times, the correlation coefficients of both one-way and absence of gazing behaviours were positive values.

D. Discussion

Timing lag between performers suggested that the performance condition without any visual cues from the co-performer was unsuitable for coordination at the points of tempo change. By contrast, there were few differences among each visual contact condition. Values of timing lag under all viewing conditions were similar to those observed in prior studies (Shaffer, 1984; Horiuchi *et al.*, 1996). Participants could thus synchronize using any part of the body.

Participants looked toward co-performers often under all visual conditions. Keller and Appel (2010) observed that piano duo performers need not look at each other under face-to-face conditions while playing a piece with only small tempo changes. In this research, participants looked at co-performers only around the points of tempo change. This indicates that visual cues were used at those times. Therefore, visual cues may be employed when performers are hard to predict co-performers' next beginning of sound. These cues may not be necessary during the less-variable parts of the piece.

Our results also indicated that a high rate of mutual gaze occurred at the points of tempo change. In this case, is mutuality important for timing coordination? Under all viewing conditions, the correlation coefficients of mutual gazing just before the points of tempo change were negative, and the correlation coefficients of one-way gazing and absence of gazing at the same points were positive. This demonstrates that only mutual gaze facilitated timing coordination. Additionally, this means that mutual visual communication may be significant during coordination although eye contact itself may not be important much. However, this result appears to be inconsistent with performers' comments on the importance of eye contact and with previous observational studies in which eye contact occurred frequently between performers. Hence, we examined the influence of eye contact itself during timing coordination in the next experiment.

III. EXPERIMENT 2

A. Aim

To investigate roles of eye contact, we measured timing lag and gazing behaviour without body movements.

B. Method

1) Participants. Twelve skilled pianists (12 female; age range = 21–41 years; mean age = 26.7 years; mean performance experience = 23.2 years) participated in the experiment. None of the pianists reported regular experience with piano duos.

2) Materials. A piece composed by a professional composer was written on a single page, because it was difficult for performers to turn pages under the fixed-head condition. The piece incorporates four changes of tempo, during which the two performers need to coordinate timing and begin to play simultaneously after a long pause.

3) Procedure. The experimental settings and measuring methods were the same as those used in Experiment 1 except that the visual-contact conditions were partner-invisible condition, only a movable-head visible, and only a fixed-head visible. The movable-head visible condition was the same condition as head alone condition in Experiment 1. The fixed-head visible condition was implemented by using a chin rest made to not encumber performance movement. We instructed participants to put their chin on it during performance. The subjects performed the piece thrice under each condition. First, they played under the partner-invisible condition. Second, they played under the other two conditions, ordered randomly for each pair.

C. Results

The average values of timing lag between the performers at four tempo change points under each visual contact condition are presented in Figure 5. The average values of timing lag were 191, 99, and 61 msec under the partner-invisible, fixed-head visible and movable-head visible conditions, respectively. The results of an analysis of variance (ANOVA) of timing lag showed significant differences between each condition (F (1.467, 95.381) = 30.196, $p < 0.001$). Multiple comparisons revealed significant differences among all conditions (Bonferroni's method, $p < 0.05$).

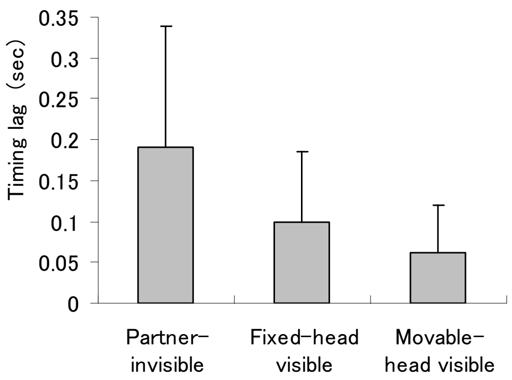

Figure 5. The average value of timing lag under each visual contact condition: partner-invisible, fixed-head visible, movable-head visible.

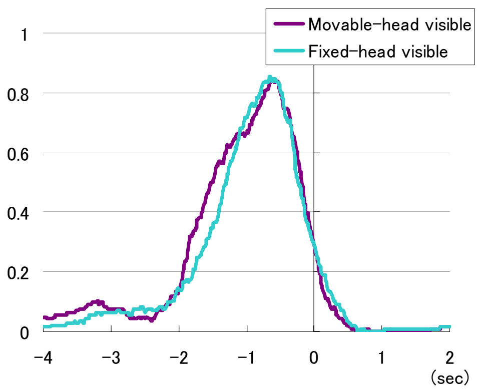

Figure 6. Gazing behaviour at the points of tempo change. The scale is the same as Figure 3.

Figure 6 indicates gazing behaviour under two visibility conditions at four points when the performers had to coordinate timing. This figure depicts the average data of 144 samples (12 participants × three trials × four points of tempo change). The results showed that the frequencies of both a performer's gaze toward the co-performer and their eye contact under each condition were highest just before the points of tempo change.

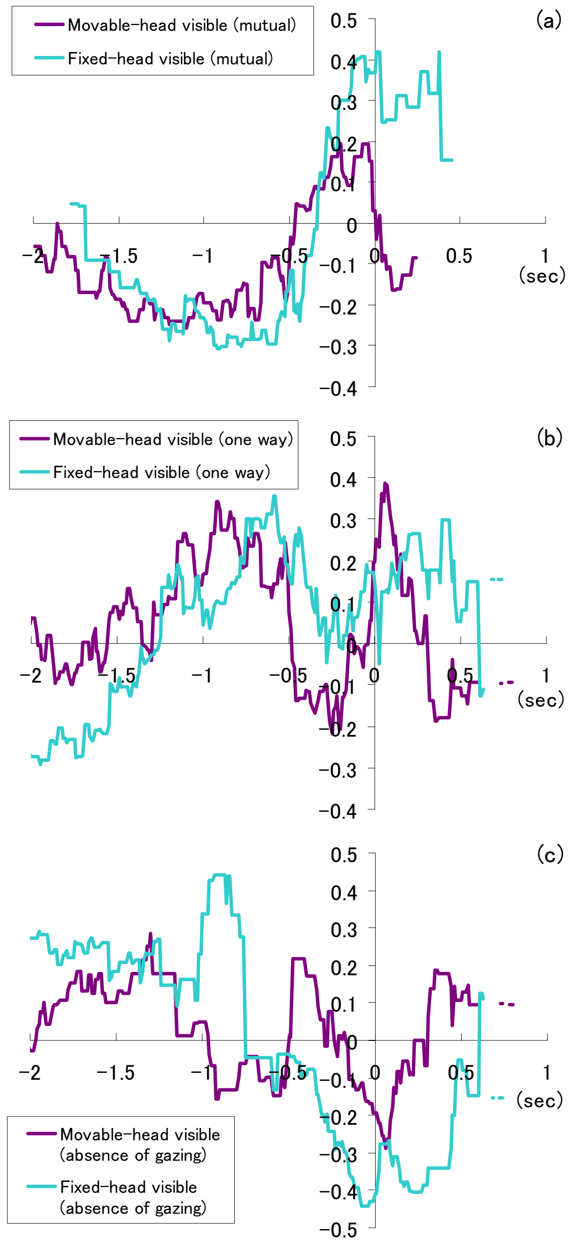

Figure 7. The correlation coefficient between the timing lag and gaze at each time point. The scale is the same as Figure 4. Each figure represents the results of (a) mutual gazing, (b) one way gazing and (c) absence of gazing under each condition.

Next, we analysed the influence of gazing behaviour on timing coordination. We calculated the point-biserial correlation coefficient between timing lag and gazing (eye contact, one-way gazing, and not gazing each other) at each point of tempo change (Figure 7). The results showed that the correlation coefficient of eye contact was significantly low just before the points of tempo change in both conditions. The minimum value of the coefficient under the fixed-head condition was -0.31 (t = -0.91 and -0.92, p = 0.009) and that under the movable-head visible condition was -0.26 (t = -1.11 and -1.10, p = 0.032). The correlation coefficients at times separated from the tempo change points by more than two seconds were difficult to construe, because gazing behaviours rarely occurred at those times.

C. Discussion

The timing lags under each condition were significantly different. The two head-visible conditions differed on the basis of the presence vs. absence of head movement cues. The timing lag under the head-visible condition in which the head could move was similar to that of the face-to-face condition in experiment 1. This means that the cue of head movement significantly facilitates coordination within performance ensembles. On the other hand, gazing or information conveyed by the face itself may not contribute to timing coordination so much; nonetheless, these cues are better than none at all.

With regard to gazing behaviour, performers looked toward their co-performers just before the points of tempo change under both head-visible conditions. Thus, the correlation coefficients of mutual gazing were negative. These results signified that mutual gazing occurring just before timing coordination points makes synchronization more accurate. Additionally, these results have the same tendency as the results of experiment 1, in which performers could use movement cues under all conditions.

Hence, mutual gaze contributes to synchronization among performers. It may also serve for the exchange of information conveyed by performers' head movement.

IV. GENERAL DISCUSSION

The results of the present study suggested that mutual gazing occurring just before timing coordination points facilitates synchronization during performances with major tempo changes. However, reduction of timing lag was not facilitated selectively by looking at any particular parts of the body. Mutual gazing without movement cues also did not contribute much to synchronization. Thus, performers accurately coordinate with co-performers by employing movement cues, and eye contact itself does not contribute much to synchronization. Eye contact during timing coordination may collaterally emerge when performers obtain their co-performers' movement information.

On the basis of the result that mutual gazing alone was related to synchronization, we conclude that performers coordinate with each other through both feedback and feed-forward mechanisms. However, synchronization processes seemed to have flexible, multimodal attributes. Goebl and Palmer (2009) showed that visual behaviour changed depending on usable auditory resources. Keller and Appel (2010) argued that pianists need not look toward co-performers when playing a piece without large variation in tempo. In our previous study on piano duos, under the leader-follower condition, we observed that gazing duration of followers were longer than that of leaders (Kawase, 2011). These studies indicate the flexibility of ensemble performance mechanisms. In other words, performers could adopt the strategy: 'use usable and necessary cues'.

The results of the present study are a bit inconsistent with performers' comments on the importance of eye contact. Additionally, eye contact has also been observed in performance situations such as live popular music performances (Davidson, 2005). Therefore, gazing may have other roles to facilitate good performance. Specifically, social aspects such as intimacy, leadership, meaningful cues, and appeal to audiences could be explored in the future studies.

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