Easing and rising of tension from presence of others in player-observer turn-taking in a driving video game: A near-infrared spectroscopy study

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Abstract

Social facilitation and social support literature, diverging with regards to increasing versus decreasing of an individual's tension, apprehend different aspects of "the presence of others." To examine the neural correlates of social presence effects, whether "the presence of others" increases or decreases an individual's tension, we measured prefrontal activation while participants performed a driving video game task using near-infrared spectroscopy (NIRS). Participants were divided into single and paired groups, and then sub-divided according to their game proficiency (high and low). The participant's task was to drive from start to goal with a default route map without an observer (single group) or under observation by an acquainted partner (paired group). The paired participants alternated their player-observer roles in a turn-taking style (Driver first and Observer second: D1-O2; Observer first and Driver second: O1-D2). The behavioral data demonstrated that, regardless of game proficiency, D1 in the paired group yielded fewer errors and longer driving time than single players, while no differences were found between D1 and D2. The tension evaluation scores in single players and D2 were higher than D1. In turn, the NIRS data revealed that, in low-proficiency players, single players and D2 who first observed D1's performance showed higher activation than D1, but neither did so in high-proficiency players. These results suggest that the presence of an acquainted partner (O1) functions positively to reduce an individual's (D1) tension in low-proficiency players. However, prior observation of another's performance may negate the positive social presence effect leading to an increase of tension in the subsequent task.

Keywords: presence of others; social facilitation; social support; individual difference; prefrontal cortex (PFC); near-infrared spectroscopy (NIRS).

Introduction

Social cognitive neuroscience is a burgeoning inter-disciplinary field combining the tools of cognitive neuroscience with questions and theories from various social sciences such as social psychology. Classical literature in social psychology has been primarily subsumed under two heads: direct interpersonal influence via interaction between persons and indirect interpersonal influence induced by the presence of others (Allport, 1920).

The latter is a fundamental, as well as the oldest, experimental research in social psychology. As put by Gordon Allport (1954), "the first experimental problem … was formulated as follows: What change in an individual's normal solitary performance occurs when other people are present?" (p. 46). The present study considers this type of question, and aims to examine the effects of social presence on the individual's neural state in a player-observer dyadic situation.

Two main existing areas of research deal with different aspects of the presence of others. One is social facilitation that investigates how social presence affects one's performance in a general way. Another is social support that focuses on the issue of how other person present relaxes an individual in the stressful environments.

Social facilitation literature has revealed inconsistent effects of social presence on performance; both performance improvement and impairment are possible. For instance, Floyd Allport (1924) demonstrated positive influence from social presence, coining the term *social facilitation* to describe the increase of response merely from the presence of others. However, not all research shows positive effects. Sometimes the presence of others impairs an individual's performance (e.g., Pessin, 1933). To explain the seemingly conflicting results, Zajonc (1965) offered a predominant interpretation based on the Hull-Spence drive theory. According to Zajonc's arousal theory, the presence of others increases an individual's general arousal level, which in turn enhances the emission of dominant responses. In a simple task, appropriate responses are typically dominant, and accordingly the presence of others will improve performance; whereas in a complex task, appropriate responses are more typically not dominant, thus performance will be impaired.

There has been general agreement with this arousal-based explanation in the following social facilitation literature, with considerable debate mostly centered on the source of arousal itself—evolving several conceptualizations such as evaluation-apprehension theory (Cottrell, 1972), monitoring theory (Guerin & Innes, 1982), and distraction-conflict theory (Baron, 1986; for review see Aiello & Douthitt, 2001; Guerin, 1993; Uziel, 2007). These theories clearly differ in their explanations for performance effects of social presence. However, attempts to pinpoint a single exclusively accurate theory have been proven unsuccessful (Guerin, 1993), due

mainly to two reasons: 1) the existing theories are not mutually exclusive—"the theories are unable to predict performance effects in such a way that eliminates other possible explanations" (Aiello & Douthitt, 2001); 2) these theories all attempt to explain why simple task performance is improved and complex task performance is impaired in presence of others without objective criteria for determining the task complexity (Uziel, 2007).

Extensive literature on social support, however, has consistently shown that social presence not only functions to increase an individual's tension level, it also decreases an individual's tension as an emotional coping recourse (e.g., Cohen & Wills, 1985; Lazarus & Folkman, 1984; Lazarus, 1999). In light of stress and coping theory, when the individual evaluates an observer as non-supportive, social presence would cause stressful circumstances, whereas when the individual appraises the others as supportive, social presence would produce relaxation.

Therefore, the incongruent results in previous social facilitation literature may be concomitant, if we accept that the effects of presence of others may be changed positively or negatively according to the cognitive setting that an observer regards others such as a dynamically changing state of the observer. For instance, proficiency in performance of a player would be one of the most critical factors that may change the meaning of others for the player him or herself.

To better understand the functional formation and mechanisms underlying the above social presence effect, there has been a growing effort to explore these outcomes in the presence of others via activity changes in the brain. Using electroencephalography (EEG), Kim, Iwaki, Uno and Fujita (2005) reported larger error-related negativity (ERN) at three brain locations (Fz, Cz, and Pz) in children when they performed a go/no-go task under observation by a friend than when performed individually. The results suggest that social presence may increase one's tension level and accordingly affect behavior as well as attitudes and feelings.

In contrast, in a functional magnetic resonance imaging (fMRI) study, Karremans, Heslenfeld, van Dillen and Van Lange (2011) demonstrated that the presence of a supportive partner reduced prefrontal activation due to easing of tension when participants endured stress during a ball-tossing game. It should be noted that, however, the partner in this fMRI study was not really present, but only virtually so via imagination. One of the reasons stems from technical limitation of brain imaging such as fMRI that is unable to assess cortical function in ambulant participants in social environments.

Near-infrared spectroscopy (NIRS) is also a non-invasive method for studying functional activation by measuring changes in the hemodynamic properties of the brain. Unlike fMRI, NIRS has few physical constraints on participants and is tolerant to motion artifact permitting serial assessments of tasks in relaxed and realistic settings (Cui, Bryant, & Reiss, 2012). In particular, Liu, Saito, and Oi

(2012) have used a 2-channel NIRS unit named as PocketNIRS due to its portability (length: 100 mm; width: 61 mm; thickness: 18.5 mm, and weight: 100 g including the batteries), and mobility (transmitting the hemodynamic signals wirelessly via Bluetooth) to investigate intrapersonal and interpersonal cognitive processes during a driving video game. They assigned participants into one control and two experimental groups. The participant's task in the control group was to drive to goal with a route-map illustrating default turning points, while the memory group was instructed to drive the memorized default route without map (intrapersonal process), and the emergency group was asked to drive with route-map but to change the default route immediately by an extrinsically given "verbal command" (interpersonal process). The results demonstrated an instantly increased activation in prefrontal cortex (PFC) during an urgent turning maneuver resulting from the "direct" interpersonal influence via verbal command, but not from the intrapersonal process.

With respect to social presence effects (i.e., "indirect" interpersonal influence), using NIRS, Ito et al. (2011) have measured prefrontal activation when participants performed a working memory task with or without evaluative observation by experimenters. The participant's task was to observe a sequence of stimuli, and to judge whether a currently presented stimulus was identical with the one presented n trials previously. They found that the participants under observation by the experimenters yielded more errors and showed higher activation in both left and right PFC than those who performed without observation. The results demonstrate that the presence of others, for instance strange experimenters in their experiment, increases an individual's tension and influences the prefrontal activation.

Early studies of social presence effects have mainly employed strangers or friends as observers. In the present study, to sustain homogeneity between single and paired groups, the participants were recruited from new students who took a general course of psychology, and the participants in the paired group were matched to soften the extreme polarization of familiarity, and to keep impartial appraisal of the pairs of acquainted participants.

We aimed to extend from the existing literature on social presence effect—demonstrating both the positive and the negative aspects of social presence in one experiment. To address these issues, we measured bilaterally the prefrontal activation in participants when they performed the goal-achievement driving task used in Liu, Saito and Oi (2012) either without an observer (single group) or under observation by a partner (paired group). Participants in both the single and the paired groups were divided into two sub-groups depending on their game proficiency (high and low). The paired participants were asked to alternate their player-observer roles in a turn-taking style (D1-O2: Driver first and Observer second; O1-D2: Observer first Driver second), exploring the possibility that in the first driving task the presence of a partner (O1) may act as a supporter of D1 in

unfamiliar experimental environments, whereas in the second driving after observation of D1's performance, O2's presence may change its role into a source of stress (i.e., non-supporter).

We tested the following three hypotheses: first, the participants in the paired group (D1) would show lower prefrontal activation than those in the single group due to easing of tension resulting from presence of an acquainted partner (positive presence effect); second, D2 would show higher prefrontal activation in the subsequent driving than D1 due to rising of tension based on observation of preceding D1's error performance (negative presence effect); third, low-proficiency players would be somewhat more sensitive to the social presence than the high-proficiency players (task proficiency effect).

Method

Participants

Sixty-two right-handed students (53 males, 9 females, age: 21 ± 2.2 years) from Nagoya University participated in the present study for the course credit. Participants were assigned to either single or (same-gender) paired groups, and subdivided according to their game proficiency (high and low). The pairs partnered with each other voluntarily, and their friendships—defined as the duration of their acquaintance—were assessed by self-report in the post questionnaire (friendship: 1.7 ± 1.4 years). All participants had normal or corrected-to-normal vision. They were informed about the purpose and safety of the experiment, and written informed consent was obtained prior to participation. This study was approved by the local ethics committee.

Materials and design

The same driving video game used in Liu, Saito and Oi (2012) was employed in the present study. During the experiment, players took a seat in front of a 32-in. monitor either individually in the single group or with a partner sitting beside in the paired group. The driving game was displayed on the monitor without sound, and the players controlled the game using a Sony game pad. Distance from the players to the monitor was set to 120 cm.

The participants were asked to obey the traffic rules and drive from start to goal with a default route-map without an observer in the single group or under observation by an acquainted partner in the paired group. Further, two instructions were given to participants in the paired group: 1) the player's performance would be evaluated by their partner as an observer, who needed to report the player's driving performance after the experiment; and 2) they would be asked to alternate their player-observer roles in a turn-taking style during the experiment. With respect to performance, in the present study we defined driving errors as that which lead to collision or driving on the pavement, however, this criterion was not explained to the participants.

Procedure

Players practiced operating the game pad for 180 s, and then they drove two training trials followed by four experimental trials with distinct routes. A single trial consisted of a driving phase and two rest phases (20 s each) before and after the driving phase.

Apparatus

The PocketNIRS (DynaSense Inc., Japan), operated at 735, 810 and 850 nm wavelengths, was used to measure the concentration changes of oxygenated hemoglobin (CoxyHb), deoxygenated hemoglobin and total hemoglobin. Two probes were attached to the forehead using double-sided adhesive sheets and centered on Fp1 and Fp2 positions, according to the international 10–20 system. Each probe consisted of one emitter optode and one detector optode located 3 cm apart. During the experiment two sets of PocketNIRS triggered by one signal were employed to measure the activation changes in paired player and observer simultaneously. The sampling rate for each channel was 10 Hz.

Data analysis

The NIRS data which contained more than 10% non-near-infrared light signals was defined as noise data. All noise data, as well as data obtained from participants who did not follow the instructions, was excluded from further analysis. Complete data was obtained from 15 single participants (6 high-proficiency, 9 low-proficiency), and 18 pairs of participants (D1: 10 high, 8 low; D2: 8 high, 10 low).

We focused on CoxyHb during the driving phase in each group, since the oxygenated hemoglobin is the most sensitive parameter of regional cerebral blood flow (Hoshi, Kobayashi, & Tamura, 2001). A linear baseline correction was conducted on the NIRS raw data to remove longitudinal signal drift using the mean value of CoxyHb during the 5 s before the driving phase. Then z-scores were calculated using the mean value and the standard deviation of CoxyHb during the baseline period in four experimental trials and in both the left and the right hemispheres, independently. To eliminate influence of the errors made by the players during driving on brain activation changes, the data during the error periods was excluded from the NIRS dataset. The z-scores were averaged finally for the driving phase over all trials, and group-averaged z-scores for each group were obtained.

Results

Behavioral data

In the present study, we calculated the driving time and counted the number of errors in the driving phase as the performance indices. Statistical analysis was conducted by means of Statistical Package for the Social Sciences (SPSS) and the significant level was set at $p < 0.05$.

Single group vs. paired group (D1) Figure 1 illustrates the driving performance including the driving time and the number of errors in the single and the paired (D1) groups. To examine the effects of the presence of a partner as an observer (O1) on the player's (D1) performance, we separately performed a two-way analysis of variance (ANOVA) on the driving time and error numbers with social presence (single and paired) and game proficiency (high and low) as the between-participants factors.
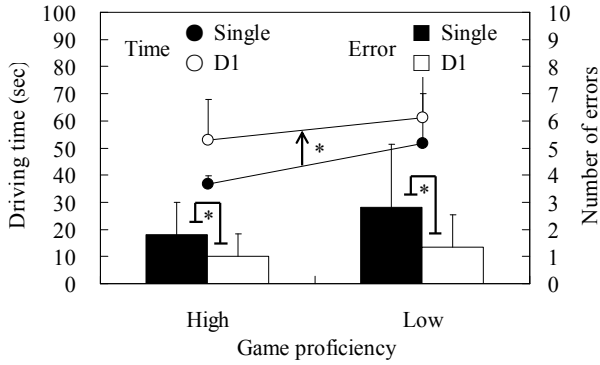

Fig.1 Mean driving time and number of errors in the single and the paired (D1) groups. D1 refers to the first driver in the paired group. Error bars represent standard deviation. * indicates $p < 0.05$.

For both the driving time and the error numbers, analyses revealed significant main effects of social presence, respectively [$F(1,29) = 4.49$, $p < 0.05$, $\eta_p^2 = 0.13$; $F(1,29) = 4.36$, $p < 0.05$, $\eta_p^2 = 0.13$]. The participants in the paired group (D1) showed fewer errors and longer driving time than those in the single group. Neither the main effects of game proficiency nor the interactions were significant. These results indicate that participants performed better under observation by an acquainted partner than when alone, regardless of their individual game proficiency.

Single vs. D2 To examine the social presence effects by O2 on D2's performance in the subsequent driving, we applied a two-way ANOVA [O2 presence (single vs. D2) × game proficiency (high vs. low)]. For error numbers, no significant differences were found between single players and D2. For driving time, the analysis revealed a significant interaction [$F(1,29) = 5.36$, $p < 0.05$, $\eta_p^2 = 0.16$]. In the simple main effect test, D2 showed a significantly longer driving time than the single high-proficiency players [$F(1,12) = 7.35$, $p < 0.05$, $\eta_p^2 = 0.38$], but low-proficiency players did not. No significant differences were found between low- and high-proficiency players in either the single players or D2. These results suggest that after prior observation of D1's performance, the positive effect of social presence on performance disappeared in the subsequent driving of D2.

D1 vs. D2 in the paired group Figure 2 shows the driving performance in D1 and D2 within the paired group. To assess the effect of the prior observation of D1's performance on the subsequent driving of D2 under observation by O2, we performed a two-way ANOVA on the driving time and the error numbers independently with observation experience (D1 and D2) and game proficiency (high and low) as the between-participants factors. The result revealed no significant differences for both the driving time and the error numbers.
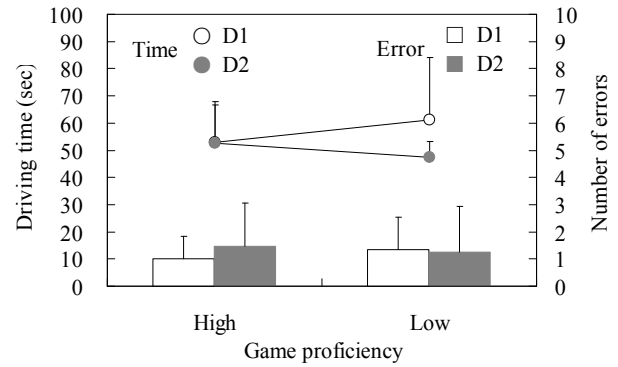

Fig.2 Mean driving time and number of errors in D1 and D2. D1 refers to the first driver in the paired group; D2 refers to the second driver in the paired group. Error bars represent standard deviation. * indicates $p < 0.05$.

Rating scores on participant's tension level The tension scores were obtained through a questionnaire filled out by the participants after the experiment. The scores were on a 5-point scale (1 = not at all tense, 5 = extremely tense). The tension index shown represents the average and standard deviation of the participant's response in two domains (unsettled feeling and stress feeling). The tension index was 1.5 (± 0.6) in the single players, 1.1 (± 0.2) in D1, and 1.4 (± 0.6) in D2, respectively. Paired t-test analysis revealed that the single players and D2 showed significantly higher tension than D1, respectively [$t(17) = 2.06$, $p < 0.05$, 1-tailed; $t(21) = 1.90$, $p < 0.05$, 1-tailed].

NIRS data

Single group vs. paired group (D1) Figure 3 shows the average values of the z-score for CoxyHb in the driving phase in the single and the paired (D1) groups. To examine the social presence effect on prefrontal activation, we performed a two-way ANOVA [social presence (2) × game proficiency (2)] in each hemisphere separately. In both the left and the right hemispheres, the analyses revealed significant main effects of game proficiency [$F(1,29) = 8.75$, $p < 0.01$, $\eta_p^2 = 0.23$; $F(1,29) = 7.29$, $p < 0.05$, $\eta_p^2 = 0.20$, respectively], and interactions [$F(1,29) = 11.10$, $p < 0.005$, $\eta_p^2 = 0.28$; $F(1,29) = 6.24$, $p < 0.05$, $\eta_p^2 = 0.18$, respectively].

In the simple main effect test, low-proficiency players showed significantly lower prefrontal activation in the paired group (D1) than those in the single group [$F_{(1,15)}$ = 11.83, $p < 0.005$, $\eta_p^2 = 0.44$; $F_{(1,15)}$ = 7.44, $p < 0.05$, $\eta_p^2 = 0.33$, respectively], but high-proficiency players did not. In the single group no significant differences were found between high- and low-proficiency players. Whereas in the paired group, low-proficiency players showed significantly lower prefrontal activation than high-proficiency players [$F_{(1,16)}$ = 13.02, $p < 0.005$, $\eta_p^2 = 0.45$; $F_{(1,16)}$ = 8.72, $p < 0.01$, $\eta_p^2 = 0.35$, respectively]. These results suggest that the presence of O1 decreased the tension level of D1 in low-proficiency players, but not in high-proficiency players.
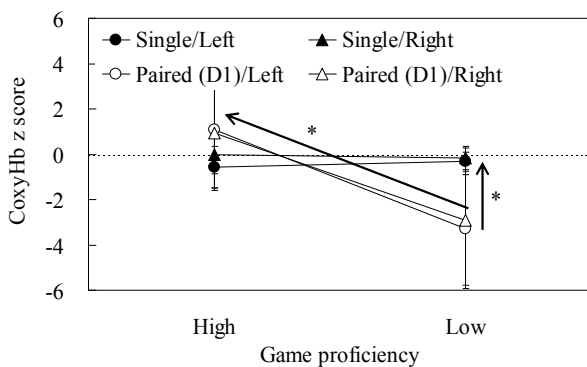

Fig.3 Average concentration changes of oxygenated hemoglobin (CoxyHb) in the driving phase in the single and the paired (D1) groups. D1 refers to the first driver in the paired group. Error bars represent standard deviation. * indicates $p < 0.05$.

Single vs. D2 To examine the effects of O2's presence on D2's prefrontal activation, we conducted a two-way ANOVA [O2 presence (2) × game proficiency (2)]. In both the left and the right hemispheres, no significant differences were found between single players and D2. The results suggest that the positive presence effect by O2 disappeared in the second driving of D2 within the same player-observer pairs.

D1 vs. D2 in the paired group Figure 4 shows the average values of the z-score for CoxyHb in the driving phase in D1 and D2. To examine the effect of the prior observation of D1's performance on D2's prefrontal activation in the subsequent driving task, we conducted a two-way ANOVA [observation experience (2) × game proficiency (2)] in both the left and the right hemispheres, respectively.

In the left hemisphere, ANOVA revealed a significant interaction between observation experience and game proficiency [$F_{(1,32)}$ = 9.22, $p < 0.005$, $\eta_p^2 = 0.22$]. No significant main effects were found. In the simple main effect test, low-proficiency players showed significantly higher prefrontal activation in D2 than in D1 [$F_{(1,16)}$ = 6.14, $p < 0.05$, $\eta_p^2 = 0.28$], but high-proficiency players did not. In D1 low-proficiency players showed significantly

lower prefrontal activation than high-proficiency players, but did not in D2.

In the right hemisphere, the results demonstrated a significant main effect of game proficiency [$F_{(1,32)}$ = 4.33, $p < 0.05$, $\eta_p^2 = 0.12$]. Neither the main effect of observation experience nor the interaction was significant. These results suggest that after prior observation of D1's performance, the presence of O2 increased the tension level of D2 in the subsequent task.
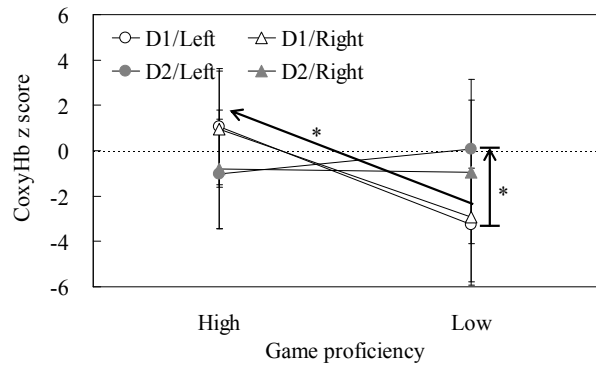

Fig.4 Average concentration changes of oxygenated hemoglobin (CoxyHb) in the driving phase in D1 and D2. D1 refers to the first driver in the paired group; D2 refers to the second driver in the paired group. Error bars represent standard deviation. * indicates $p < 0.05$.

Discussion

The present study was designed to examine the neural substrate of social presence effects in a natural player-observer environment. To achieve this goal, we measured prefrontal activation in participants without an observer (single group) and with an observer (paired group) during a driving video game using PocketNIRS. In this regard, we tested whether two paired groups (driver first D1 and driver second D2) manipulated in a player-observer turn-taking style consistently demonstrated lower prefrontal activation than the single players, regardless of prior experience of observation in D1 and D2.

Three main findings were obtained, and will be discussed in turn. First, the present data demonstrated lower prefrontal activation in the paired group (D1) than in the single group. The result is consistent with our hypothesis suggesting that the presence of others may serve as a supportive role relaxing an individual (positive presence effect).

Second, in the same social environment the present data revealed higher prefrontal activation in D2 than in D1. This result indicates that the supportive role of the observer may change to a non-supportive role, and increase an individual's tension (negative presence effect).

Third, as predicted, the above two effects were confirmed only in low-proficiency players, but not in high-proficiency players (task proficiency effect).

A unique aspect of the present study is that we demonstrated controversial aspects of social presence effects within one experiment: the presence of others may act positively to relax the individual as well as negatively to stress the individual, depending upon how the individual evaluates the role of the observer (supporter or non-supporter). Previous social facilitation studies have mostly emphasized the negative aspects of social presence leading to rising of tension. Social presence, however, is not just a major source of stress. Social support literature has also demonstrated the benefits of the presence of others to the individual's level of tension (e.g., Cohen & Wills, 1985; Lazarus & Folkman, 1984). Consistent with social support, the present study confirmed that the presence of others could reduce an individual's tension level. It is particularly interesting that after the prior observation of the partner's performance, the supportive effect of social presence disappeared; the supportive role of the observer may change to non-supportive role in the subsequent task.

The present study provides an important theoretical implication. The early social facilitation and social support literature has mainly focused on two distinct aspects of social presence effects, respectively (e.g., Cohen and Wills, 1985; Zajonc, 1965). The present study bridges a gap between them suggesting that research into social presence effects would benefit from combining the ideas of two theories and addressing the role of observer as an important moderating variable subject to subjective appraisal of the observer.

In conclusion, the present study suggests that research into social presence effect would be benefited by addressing individual differences, specifically how an individual evaluates the role of others, as well as the individual's task proficiency. Further study is needed to explore the neural correlates of the explicit role of the presence of others during cooperation and competition.

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