Gender and Peer Effects on Performance in Social Networks[☆]

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Abstract

We investigate whether peer effects at work differ by gender and whether the differences -if any- depend on work organization. We develop a social network model with gender heterogeneity that we test using a real-effort laboratory experiment. We compare directed networks (with a unidirectional flow of information) and undirected networks (with a bidirectional flow of information). Our results are consistent with the hypothesis that competitive rivalry is the basic mechanism through which peer effects influence individuals' behavior. Males and females behave differently. The former are influenced by their peers in both networks whereas the latter are indifferent to their peers' performance in undirected networks. An interpretation is that females perceive the undirected networks as being more competitive.

Key words: Gender, peer effects, social networks, work effort, experiment.

JEL-codes: C91, J16, J24, J31, M52.

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1. Introduction

Everyday life offers many examples whereby individual labor supply and performance not only depend on a worker's wage rate, nonwage income, and characteristics, but also on social interactions. Since Kandel and Lazear (1992)'s seminal theoretical contribution, several empirical studies have found positive peer effects in settings as varied as tournaments, piece rates (Azmat and Iriberri, 2016; Blanes i Vidal and Nossol, 2011) and fixed compensation schemes (Falk and Ichino, 2006; Mas and Moretti, 2009; Kuhnen and Tymula, 2012).[1] Others, in contrast, have found either a null or a weak positive effect (Guryan et al., 2009; Bellemare et al., 2010; Eriksson et al., 2009; van Veldhuizen et al., 2018). Some have even found a negative peer effect amongst the lowest-performing (Barankay, 2012) and the disappointment-averse workers (Gill and Prowse, 2012). Azmat and Iriberri (2016) also report a short-term negative effect of feedback at school on educational performance.

Surprisingly, the literature has seldom addressed gender-specific peer effects on work effort. A few noticeable exceptions are Bellemare et al. (2010) who found that peer effects on productivity at work differ by gender only under fixed wages but not when subjects are paid using piece rates. Hahn et al. (2017) provide evidence that feedback on peer math performances has a different effect according to gender. Low-ability females work harder when working with peers. Lavy and Sand (2017) find that the number of friends and their characteristics have a positive effect on students' academic progress, but no significant differences between males and females.

The structures of links between workers are various. Thus, the manner in which information flows through a "social network" is specific to each work environment. Moreover, the influence of peer effects is likely to vary depending on the structure of this environment. Yet, despite the pervasiveness of such social networks (Jackson, 2010, 2011), most studies of peer effects at work assume that individuals interact within groups. This amounts to assuming that the population is partitioned into groups, and that individuals are affected by all others in their group and by none outside of it. More realistically, each worker may have his own reference group. Also, while peer effects in social networks have been studied in various contexts, their analysis on the labor market has focused for the most part on the transmission of information about job opportunities (Laschever, 2011; Calvó-Armengol et al., 2009) and the role of referrals (Topa, 2011). The role of social networks on work effort has seldom been investigated.[2]

[1]For example, in Falk and Ichino (2006), subjects had to wrap envelopes either alone in a room, or alongside a co-worker. Working in pairs induced a higher output level. In a large grocery chain, Mas and Moretti (2009) found positive peer effects on productivity when cashiers could be observed by coworkers. No such effect was found when they could only observe others' output without being observed themselves. Kuhnen and Tymula (2012), in contrast, conducted a lab experiment that insured feedback was private and anonymous; they found that learning about one's own rank increased work effort presumably out of concern for self-esteem.

[2]Using field experiments, Bandiera et al. (2009, 2010) show how friendship at work modulates the impact

Our paper aims at addressing these issues. First, we investigate peer effects on effort at work using a social network model with gender heterogeneity, inspired by the approach developed by Arduini et al. (2016). More precisely, our theoretical framework generalizes the standard linear-in-means approach (e.g., Manski, 1993; Bramoullé et al., 2009; Blume et al., 2015) according to which an individual's behavior can be influenced by the mean behavior and the mean characteristics of his peers. This is done by allowing the impact of the performance (the "endogenous" peer effects) and the characteristics of the peers (the "contextual" or "exogenous" peer effects) to vary across gender. To estimate the model, we design a series of laboratory experiments in which subjects are paid according to a piece rate scheme to perform a real task repeatedly.

Our second aim is to develop a framework which allows to compare performance across gender when the work environment varies. This contribution is important since, to our knowledge, no study has ever addressed this issue in the literature. More precisely, two work organizations are considered, each consisting in a different treatment: *directed* networks and *undirected* networks. In the Directed (Sequential) Network treatment, subjects are randomly assigned to peers who participated in a previous Baseline treatment in which they performed the exact same tasks in isolation. Subjects are informed about the mean performance, wage and individual characteristics of their peers. Thus, in these directed bipartite networks, information flows one-way from peers to subjects. This more or less mimics a situation whereby workers learn about the output level of their peers in a previous work shift. In the Undirected (Simultaneous) Network treatment, subjects are also randomly assigned to peers but they interact in real-time and information flows in two directions: from peers to subjects and from subjects to peers. This arrangement mimics that of employees working in call centres or along an assembly line who can thus observe the performances of their co-workers located nearby, and *vice versa*.

Also our approach allows us to characterize the channels through which peer effects influence individual behavior. Since the workers cannot communicate and their outputs are independent in our design, we distinguish three potential mechanisms that may explain their existence: social learning, competitive rivalry and conformity (see Cooper and Rege, 2011). As we will see below, our empirical framework minimizes social learning and thus allows to focus on competitive rivalry and conformity as possible sources of peer effects. Furthermore, exploiting the treatments wherein subjects are isolated, we provide a test of pure competitive rivalry based on Boucher and Fortin (2016). The latter have shown that the effect of individual characteristic on outcome under conformity is smaller (in absolute value) when individuals interact than when playing in isolation, whereas there are no such differences under competitive rivalry. The intuition is that deviation from one's peer perfor-

of incentive schemes on productivity. More closely related to our approach, Lindquist et al. (2015) use data from the call center of a mobile network operator and a field experiment. They find evidence of both a local average network effect on productivity, attributed to conformism and peer pressure, and a local aggregate effect that results from knowledge spillovers.

mance entails a psychic cost under conformity alone, which reduces the impact of individual characteristics.

Designing exogenous networks in the lab eases the identification of peer effects for at least three reasons. First, by randomly assigning subjects across networks, it ensures the absence of endogeneity biases arising from the fact that individuals self-select in their reference group (*e.g.*, no correlated effects due to homophily). Second, it guarantees knowledge of the true reference group (to the researcher), that is, who interacts with whom free of any measurement error. Third, Bramoullé et al. (2009) have shown that when there are no correlated effects, the endogenous and contextual effects are identified in the standard linear-in-means model when individuals do not interact in groups.[3] Based on Arduini et al. (2016)'s conditions, we extend this property to the case of gender heterogeneity. Therefore, forming properly designed networks in the lab allows us to identify peer effects.

Our empirical strategy consists in estimating the gender-specific directed network model using a clustered random effects approach, and the undirected network model using a panel spatial pseudo-maximum likelihood method. Our results show that peer effects strongly differ between males and females. In particular, we find that males' performances are positively linked to that of their peers in both treatments. Females, on the other hand, respond positively to their peers' performances in the directed networks, but not so in the undirected networks. Thus, when information flows in both directions, females behave as if their peers' performance and characteristics were irrelevant, which is in stark contrast to their male counterparts. Variants of the informational content of the Baseline and Directed Network treatments are used to investigate the sensitivity of the estimates of the Directed Network treatment. These variants aim at replicating the information that is available to the subjects and their peers in the Undirected Network treatment. Because both female and male performances are the same as in the initial Directed Network treatment, we conclude that it is the combination of the simultaneity and the bi-directionality of the flow of information in the Undirected Network treatment that determines how females react to the performance of their peers.

According to our parameter estimates, the endogenous peer effects result from competitive rivalry, not from conformity. Hence, the fact that females respond to the performance of their peers in the directed networks, but no so in the undirected ones, suggests that they perceive the former as being different from the latter. A possible interpretation is that females may deem the undirected networks as being somewhat more competitive. Peer performance in the directed networks, on the other hand, may be viewed as a reference point when setting personal goals. This interpretation is rooted in the literature according to which females, as opposed to males, are found to be less responsive to financial

[3] In contrast, when a social network is composed of a set of diads (*i.e.*, couples) the peer effects are not identified when interacting in groups (Bramoullé et al., 2009). This is a particular case of the so-called reflection problem (Manski, 1993).

incentives in more competitive environment (Gneezy et al., 2003; Niederle and Vesterlund, 2007; Datta Gupta et al., 2013). Our results suggest that these differences also hold for non-monetary, informational, incentives. They may shed light on the causes of gender differences in occupational statuses and career paths.

The remainder of the paper is structured as follows. Section 2 presents our theoretical model of peer effects at work. Section 3 discusses the peer effects mechanisms in our approach. Section 4 describes the experimental design and procedures. Section 5 presents our econometric strategy and our results. Section 6 concludes.

2. Theoretical setup

Consider three types of work arrangements with increasing levels of interactions. In all three cases, subjects are asked to perform the same sequence of mathematical tasks. At one extreme (Baseline treatment), subjects work in isolation. At the other extreme (Undirected Network treatment), they interact with peers in a given network configuration and are made aware of the latter's mean performance in real-time as the game unfolds. As an intermediate case (Directed Network treatment), subjects are randomly matched to peers from the Baseline treatment and information about peers' performance and characteristics flows one-way.

2.1. Baseline treatment

A treatment includes s sessions (or networks) indexed by l, with $i = 1, \ldots, n_l$ subjects who perform a task for a total of $t = 1, \ldots, T_l$ periods. In each session l, there are n_l^m males (or type-m) and n_l^f females (or type-f) (with $n_l^m + n_l^f = n_l$). For notational convenience, we assume, for the moment, that there is a single session per treatment (with $n_l = n$, $n_l^m = n^m$, $n_l^f = n^f$ and $T_l = T$). Total time per period is fixed and allocated between (pure and on-the-job) leisure and work. Work (or work effort) is proxied by the per period individual production and subjects are paid a piece rate for each unit of production.[4] We order the vectors and matrices in each treatment so that the first rows correspond to type-m subjects and the remaining rows to type-f subjects.

We assume that preferences for consumption and leisure is represented by the direct utility function that rationalizes the semi-log effort function (see Heckman, 1974) when maximized under the budget and time constraints. This function is both parsimonious and realistic as it is consistent with a decreasing wage effect as effort increases. It is written as:

$$e_{it}^j = \alpha_i^j + \alpha_1^j w_{it}^j + \eta_{it}^j, \tag{1}$$

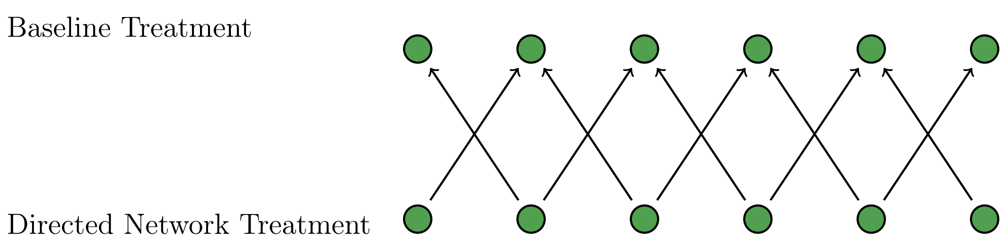
[4]In principle, a production function could be specified that would relate output to work effort, other inputs and unobservable shocks. However, it would be difficult to identify technology from preferences in the model. Thus, following Dickinson (1999), we assume that work effort can be proxied by output.

with $E(\eta_{it}^j|\boldsymbol{w}_i^j, \alpha_i^j) = 0$, $E(\alpha_i^j|\boldsymbol{w}_i^j) = E(\alpha_i^j)$, $j = m, f$, $i = 1, \ldots, n^j$, $t = 1, \ldots, T$. The variable e_{it}^j is type-j individual i's effort at period t, w_{it}^j is his/her piece rate wage (in log)[5], α_i^j is a time invariant individual effect, η_{it}^j is an idiosyncratic individual term, and $\boldsymbol{w}_i^j = (w_{i1}^j, w_{i2}^j, \ldots, w_{iT}^j)$.[6] The parameters of equation (1) can be estimated using a random effects procedure[7] as the model assumes both strict exogeneity[8] of $\boldsymbol{w}_i^j$ and orthogonality between α_i^j and $\boldsymbol{w}_i^j$. Moreover, panel robust standard errors (clustered at the individual level) are used to conduct statistical inferences since idiosyncratic errors are likely to be serially correlated across t.

2.2. Directed Network treatment

In the Directed Network treatment, the networks are structured such that the information on wage and performance flows from the individuals in the Baseline treatment to individuals in the Directed Network treatment. Figure 1 describes this situation, where each node represents an individual and each arrow points towards peers (following the convention in social network theory, arrows indicate the direction of the relationship not that of the flow of information).

Figure 1: Graph of a Directed Network



Subjects in the Directed Network treatment are each matched to a specific reference group, N_i^j, that comprises n_i^j individuals from the Baseline. They are informed about

[5]For notational simplicity, we assume only one observable characteristic, the piece rate wage, which is randomly determined in the experience. In the empirical section, we introduce other exogenous explanatory variables: the show-up fee (as a proxy for nonlabor income), age, the relative family wealth, the proportion of males in the session, a dummy for being student in the engineering school, and time.

[6]Substituting the budget constraint in the direct utility function, the quadratic utility function which is obtained and rationalizes equation (1) can be written as: $U_{it}^j(e_{it}^j; w_{it}^j, \eta_{it}^j) = (\alpha_i^j + \alpha_1^j w_{it}^j + \eta_{it}^j)e_{it}^j - (e_{it}^j)^2/2$.

[7]We also estimated a fixed effects model and we obtained very similar estimates for time-varying covariates.

[8]In the general case with many sessions, we allow for session fixed effect for $l = 1, \ldots, s$. These may possibly be correlated to the explanatory variables and aim at capturing changing laboratory environments (weather, daytime, *etc.*).

the average performance and wage of their peers at the beginning of each period. Social interactions are introduced in the sequential model by assuming a linear-in-means semi-log effort function:[9]

$$e_{it}^j = \beta_i^j + \beta_1^j w_{it}^j + \beta_2^j \frac{1}{n_i^j} \sum_{k \in N_i^j} e_{kt} + \beta_3^j \frac{1}{n_i^j} \sum_{k \in N_i^j} w_{kt} + u_{it}^j. \tag{2}$$

with $j = m, f,\ \ i = 1, \ldots, n^j,\ \ t = 1, \ldots, T$. Assumptions on the error component terms, β_i^j and u_{it}^j, are the same as those in the Baseline treatment. The performance and contextual peer effects are captured by β_2^j and β_3^j, respectively. In this linear-in-means model, competitive rivalry and/or conformity correspond to having $\beta_2^j > 0$. In section 3, we show how is it possible to distinguish between these two mechanisms using results from the Baseline treatment. Note also that our model assumes between-gender heterogeneity but within-gender homogeneity. Indeed, the peer effects of male and female subjects are assumed to be the same for an individual of a given gender.[10] In the Directed Network treatment, no endogeneity issues arise due to simultaneity of outcomes since all explanatory variables are assumed strictly exogenous. Assuming also orthogonality between β_i^j and these variables, equation (2) is a random effects model.

It is useful to combine the Baseline and Directed Network treatments into a single model in order to compare them to the Undirected Network treatment discussed below. First, define the type-j interaction matrix $\boldsymbol{R}^j$, with a zero diagonal, where the typical element is $r_{ik}^j = 1/n_i^j$ if k belongs to the Baseline treatment and is a peer of type-j subject i in the Directed Network treatment, and $r_{ik}^j = 0$, otherwise. The vector $\boldsymbol{R}^j \boldsymbol{e}_t$ corresponds to the mean performance of type-j individuals' reference group at t. By design, the value is equal to 0 for Baseline individuals. Similarly, the vector $\boldsymbol{R}^j \boldsymbol{w}_t$ corresponds to the mean wage rate of type-j individuals' reference group at t. In this section, we assume that $\alpha_1^j = \beta_1^j$, with $j = m, f$.[11] If these equalities hold, then combining the two models will yield more efficient parameter estimates.The pooled set of Baseline and Directed Network individuals is said to form a *directed bipartite network*. Eqs.(1) and (2) can then be combined into a single *pooled* model:

[9]Later in the paper, we perform tests based on quantile regressions that do not reject linear-in-means peer effects.

[10]A more general model would allow individuals to respond differently to peers of each gender, *i.e.*, it would include four heterogeneous effects (*ff, fm, mf, mm*) rather than two (*f, m*). For the sake of simplicity and given the relatively small size of our sample, we only consider between-gender heterogeneity. However, the proportion of male peers is included as a contextual variable in the econometric specification but turns out to be statistically significant only in the Simultaneous specification of the Gender-Heterogeneous model and for females (*p-value* = 0.077).

[11]As discussed in section 3, these assumptions hold when the mechanism through which peer effects influence behavior is pure competitive rivalry. They are also tested in the empirical section of the paper.

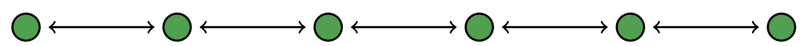
$$\boldsymbol{e}_t^j = \boldsymbol{\beta}^j + \beta_1^j \boldsymbol{w}_t^j + \beta_2^j \boldsymbol{R}^j \boldsymbol{e}_t + \beta_3^j \boldsymbol{R}^j \boldsymbol{w}_t + \boldsymbol{u}_t^j, \tag{3}$$

with $j = m, f$, $t = 1, \ldots, T$, where $\boldsymbol{e}_t^j$, $\boldsymbol{\beta}^j$ and $\boldsymbol{u}_t^j$ are respectively the concatenated $(n^j \times 1)$ vector of effort levels, time invariant individual effects, and idiosyncratic individual terms of type-j subjects at time t, in the Baseline and Directed Network treatments. This specification allows for between-gender heterogeneous peer effects since the parameters are all indexed by $j = m, f$. This random effects model is identified as long as the usual (full) rank condition for generalized least squares is satisfied.

2.3. Undirected Network treatment

In the Undirected Network treatment, information on performance and characteristics flows between subjects and peers in real time. Figure 2 describes this situation, where each node represents an individual, and shows how we implemented this type of network in the experiment, as described later.

Figure 2: Graph of an Undirected Network



Because subjects likely influence one another, we must make an assumption about preferences for this type of game to reach an equilibrium. Thus each subject is assumed to behave non-cooperatively and to ignore the fact that his own performance may influence other subjects in the network. This is equivalent to assuming that, at the equilibrium, each subject correctly anticipates the mean performance of his peers and behaves accordingly. In other words, a non-cooperative Nash social equilibrium arises because subjects are assumed to form self-consistent expectations.[12]

At the Nash equilibrium, the best response equation for type-j subjects, given the mean effort and characteristics of their peers, is given by:

$$\boldsymbol{e}_t^j = \gamma^j \boldsymbol{\iota}^j + \gamma_1^j \boldsymbol{w}_t^j + \gamma_2^j \boldsymbol{G}^j \boldsymbol{e}_t + \gamma_3^j \boldsymbol{G}^j \boldsymbol{w}_t + \boldsymbol{\varepsilon}_t^j, \tag{4}$$

with $E(\boldsymbol{\varepsilon}_t^j | \boldsymbol{w}) = 0$, $j = m, f$, $t = 1, \ldots, T$, where $\boldsymbol{\iota}^j$ is a $(n^j \times 1)$ vector of ones, $\boldsymbol{G^j}$ is a row-normalized non-stochastic interaction matrix for type-j subjects, with a zero diagonal, and with $g_{ik}^j = 1/n_i^j$ if k is a peer of the type-j subject i, and 0 otherwise. The endogenous

[12]We describe the convergence procedure to the Nash equilibrium in the section on the experimental design.

(performance) peer effect and the contextual effect are measured by $\gamma_2^j$and γ_3^j, respectively. It is standard to assume that $|\gamma_2^j| < 1$.[13] For simplicity, we assume for the moment that $\boldsymbol{\varepsilon}_t^j$ is a vector of errors whose elements are i.i.d. with variance given by σ^2, for all i, t, and $j = m, f$.[14]

It is worth emphasizing that equation (3) for directed networks and equation (4) for undirected networks differ in three important aspects. First, while in directed networks subjects in a given session are matched to peers who have played in isolation in a previous session, in the undirected networks social interactions occur in real time in the same session. Since the models do not reflect the same informational environment, we allow the parameters of these two equations to be different. This point is crucial for distinguishing behaviors across genders. Second, the vector of the mean reference group's performance, $\boldsymbol{R^j e}_t$, is exogenous in equation (3) whereas the corresponding variable, $\boldsymbol{G^j e}_t$ is endogenous in equation (4). The reason is that, in the Undirected Network treatment, a subject is influenced by his peers and *vice versa*. Third, in the Undirected Network treatment, we assume a constant coefficient for each gender (*i.e.*, γ^m and γ^f) and not a (time invariant) individual effect as in the Baseline and Directed Network treatments. This allows us to simplify the estimation of the undirected network model.[15]

To estimate this heterogeneous social network model, it is first important to establish the conditions under which it is identified. To do so, first vertically concatenate the vectors and matrices in equation (4) with respect to gender $j = m, f$. Then, define the two $n \times n$ type-j social interaction matrices $\underline{\mathbf{G}}^j$ such that $\underline{g}_{ik}^j = 1/n_i^j$ if k is a peer of the type-j subject i, and 0 otherwise. It is clear that $\underline{\mathbf{G}}^m + \underline{\mathbf{G}}^f = \mathbf{G}$, where $\mathbf{G}$ is the row-normalized interaction matrix for the entire set of subjects. Define the $n \times 1$ vector $\boldsymbol{d}_t^m$ of dummy variables of male indicators d_{it}^m such that $d_{it}^m = \mathbf{1}(j_i = m)$, for all $i = 1, \ldots, n$, where j_i is the individual i's gender. Similarly, define the vector $\boldsymbol{d}_t^f$ of dummy variables for female subjects. By definition, $\boldsymbol{d}_t^m + \boldsymbol{d}_t^f = \boldsymbol{\iota}_t$, where $\boldsymbol{\iota}_t$ is a $n \times 1$ vector of ones. Now define a $n \times 1$ vector $\underline{\boldsymbol{w}}_t^m = I_t^m \boldsymbol{w}_t$, where $I_t^m \equiv diag(\boldsymbol{d}_t^f)$. The element $\underline{w}_{it}^m$ is equal to w_{it}^m when the subject i is a male, and 0 when the subject i is a female. Similarly, define $\underline{\boldsymbol{w}}_t^f = I_t^f \boldsymbol{w}_t$. Since $I_t^m + I_t^f = I_t$, one has $\underline{\boldsymbol{w}}_t^m + \underline{\boldsymbol{w}}_t^f = \boldsymbol{w}_t$. Also, denote $\boldsymbol{e_t} = (\boldsymbol{e}_t^{m\prime}, \boldsymbol{e}_t^{f\prime})'$. The best response function at time t and at the Nash equilibrium can be written as:

$$\boldsymbol{e}_t = \gamma^m \boldsymbol{d}_t^m + \gamma^f \boldsymbol{d}_t^f + \gamma_1^m \underline{\boldsymbol{w}}_t^m + \gamma_1^f \underline{\boldsymbol{w}}_t^f + \gamma_2^m \underline{\boldsymbol{G}}^m \boldsymbol{e_t} + \gamma_2^f \underline{\boldsymbol{G}}^f \boldsymbol{e_t} + \gamma_3^m \underline{\boldsymbol{G}}^m \boldsymbol{w}_t + \gamma_3^f \underline{\boldsymbol{G}}^f \boldsymbol{w}_t + \boldsymbol{\varepsilon}_t. \quad (5)$$

[13] More generally, stationarity requires that $1/\omega_{min}^j < \gamma_2^j < 1/\omega_{max}^j$, for $j = m, f$, where ω_{min}^j and ω_{max}^j denote the smallest (i.e., most negative) and the largest eigenvalue of the matrix $\boldsymbol{G}^j$.

[14] In the empirical section, this assumption is relaxed.

[15] As discussed later, our pseudo-maximum likelihood approach takes into account both the endogeneity (reflection) and the serial correlation problems (using panel clustered standard errors).

Using an obvious notation, the *macro* model, which includes all periods (in finite number), can be written as:

$$\boldsymbol{e}_T = \gamma^m \boldsymbol{d}_T^m + \gamma^f \boldsymbol{d}_T^f + \gamma_1^m \underline{\boldsymbol{w}}_T^m + \gamma_1^f \underline{\boldsymbol{w}}_T^f + \gamma_2^m \underline{\mathbb{G}}^m \boldsymbol{e}_T + \gamma_2^f \underline{\mathbb{G}}^f \boldsymbol{e}_T + \gamma_3^m \underline{\mathbb{G}}^m \boldsymbol{w}_T + \gamma_3^f \underline{\mathbb{G}}^f \boldsymbol{w}_T + \boldsymbol{\varepsilon}_T, \quad (6)$$

with $E(\boldsymbol{\varepsilon}_T|\boldsymbol{w}_T) = 0$. Also, $\underline{\mathbb{G}}^j = \text{diag}(\underline{\boldsymbol{G}}^j)$ is the block-diagonal type-j interaction matrix for the T periods, with $\underline{\mathbb{G}}^m + \underline{\mathbb{G}}^f = \mathbb{G}$. All vectors in equation (6) have a $Tn \times 1$ dimension, with $\underline{\boldsymbol{w}}_T^m \equiv \mathbb{I}^m \boldsymbol{w}_T$, $\underline{\boldsymbol{w}}_T^f \equiv \mathbb{I}^f \boldsymbol{w}_T$, and $\mathbb{I}^m + \mathbb{I}^f = \mathbb{I}$.

Finally, using equation (6), the *macro reduced form* is given by:

$$\boldsymbol{e}_T = \mathbb{S}^{-1}(\gamma^m \boldsymbol{d}_T^m + \gamma^f \boldsymbol{d}_T^f + \gamma_1^m \underline{\boldsymbol{w}}_T^m + \gamma_1^f \underline{\boldsymbol{w}}_T^f + \gamma_3^m \underline{\mathbb{G}}^m \boldsymbol{w}_T + \gamma_3^f \underline{\mathbb{G}}^f \boldsymbol{w}_T + \boldsymbol{\varepsilon}_T), \quad (7)$$

where $\mathbb{S} = \mathbb{I} - \gamma_2^m \underline{\mathbb{G}}^m - \gamma_2^f \underline{\mathbb{G}}^f$. Since $|\gamma_2^j| < 1$ for $j = m, f$, the inverse matrix $\mathbb{S}^{-1}$ exists.

In our setting, identification means that a consistent estimator of the parameters of the model (6) exists. Assuming standard regularity conditions (see Appendix A in Arduini et al., 2016), we have the following proposition:

Proposition 1. *Assume that the model (6) holds. Assume also that* $|\gamma_2^j| < 1$*, and that* $\gamma_1^j \gamma_2^j + \gamma_3^j \neq 0$*, for* $j = m, f$*. If the matrices* $\mathbb{I}^m, \mathbb{I}^f, \underline{\mathbb{G}}^m, \underline{\mathbb{G}}^f, \underline{\mathbb{G}}^{m^2}, \underline{\mathbb{G}}^{f^2}, \underline{\mathbb{G}}^m \underline{\mathbb{G}}^f, \underline{\mathbb{G}}^f \underline{\mathbb{G}}^m$ *are linearly independent, then the parameters of the model (6) are identified.*

Proof. This proposition is a simple application of Proposition 1, (see case 1.(a), case 1.(b), and their symmetric counterparts) in Arduini et al. (2016).[16] □

From this proposition, it follows that the characteristics of type-m and type-f peers (and their interactions) of distances 2, 3 ..., in the network, are appropriate identifying instruments.

The standard homogeneous linear-in-means model is a particular case of this model. It is obtained when assuming that $\gamma^m = \gamma^f = \gamma$ and $\gamma_r^m = \gamma_r^f = \gamma_r$, for $r = 1, 2, 3$. Under these assumptions, equation (6) can be written as:

$$\boldsymbol{e}_T = \gamma \boldsymbol{\iota}_T + \gamma_1 \boldsymbol{w}_T + \gamma_2 \mathbb{G} \boldsymbol{e}_T + \gamma_3 \mathbb{G} \boldsymbol{w}_T + \boldsymbol{\varepsilon}_T, \quad (8)$$

with $E(\boldsymbol{\varepsilon}_T|\boldsymbol{w}_T) = 0$. In that case, the identification conditions correspond to those of the Bramoullé et al. (2009) model. More precisely, the model is identified if $\gamma_1\gamma_2 + \gamma_3 \neq 0$, and if the matrices $\mathbb{I}, \mathbb{G}, \mathbb{G}^2$ are linearly independent. The latter condition is satisfied in our Undirected Network treatment since subjects do not interact in groups.

The model (6) is estimated using a panel spatial maximum likelihood (ML) approach with two lagged spatial dependent variables to take into account gender heterogeneity in

[16]Note that Proposition 1 in Arduini et al. (2016) is more general than our own proposition, since it also applies to the case where individuals may respond differently to peers of each gender.

endogenous peer effects.[17] Robust panel standard errors (clustered at the subject level) are used to provide valid inference in the presence of serial correlation. Moreover, the ML procedure is less sensitive to various implementation issues such as the choice of instruments in the IV approach.[18]

3. Peer effects mechanisms

Based on Cooper and Rege (2011), one may distinguish at least three potential channels through which peer effects may affect agents' behavior: social learning, competitive rivalry and conformity. First, social learning occurs when the information set is modified through the interactions between an individual and his reference group. Second, competitive rivalry refers to the positive relation between peer performance and the marginal utility of own performance.[19] Finally, conformity refers to social preferences in that an individual's utility increases when his outcome nears that of his peers.

Social learning is unlikely to occur in our design since the subjects are asked to perform a straightforward task and they are prevented from communicating.[20] To distinguish between the two other mechanisms, we refer to Boucher and Fortin (2016) who have shown that using isolated individuals in a given network allows to test for the existence of rivalry and conformity. Under pure competitive rivalry, they have shown that the coefficients of the individual's exogenous characteristics (such as piece rate wage, show-up fee and age, in our design) are the same regardless of whether the agents are isolated (as in our Baseline treatment) or not (as in the Directed Network treatment). In contrast, under pure conformity, they have shown that the impact of the exogenous characteristics is different (smaller in absolute value) when individuals interact with peers than when they are isolated. The basic intuition is that, under conformity, there is a utility cost for individuals to perform differently from their peers, which reduces the effects of individual characteristics.

[17] Of course, when a 2SLS estimator of the model (6) is identified, the ML estimator is also identified since it imposes more structure on the error terms.

[18] We also estimate the model (6) using fixed effects IV. However, the parameter estimate of peer performance was very close to the one obtained using a ML approach but much less precise. Moreover, one disadvantage of the fixed effects IV estimator is that it cannot identify the individual and contextual effects that are time invariant.

[19] In a sense, competitive rivalry is akin to complementarity (e.g., see Calvó-Armengol et al., 2009), as it motivates an individual to increase his performance when his peers become more productive. However, complementarity can be ignored in our design since the subjects cannot communicate and their outputs are independent. Therefore we refer to rivalry instead of complementarity.

[20] A referee rightly mentioned that our design may not be totally void of learning. Indeed, since the subjects are informed at the outset that they have to perform the same sequence of tasks as their peers, the latter's performance may convey information about the relative difficulty of the task. This is clearly a limitation of our approach. However, because the tasks are quite straightforward, and since unobserved variables such as concentration or fatigue may also blur peer performance, we nevertheless think there is relatively little scope for learning in our design.

4. Experimental design and procedures

In Section 2 we have detailed three network configurations (treatments) through which peer effects may readily be identified and measured. Yet, the previous section has underlined two likely mechanisms through which peers effects may arise (rivalry/conformity). So while the theoretical setup insures the identification of the peer effects, it is silent with respect to their true nature. Fortunately, it turns out the informational contents of the treatments are rich enough to allow to discriminate between the two as shown below.[21] The challenge we face in designing laboratory experiments is to mimic these treatments as closely as possible so as to insure the unbiasedness and efficiency of the parameter estimates and thus of the related test procedures. The experimental design thus implements a linear-in-means model that follows directly from the theoretical setup. It uses a between-subjects protocol with random assignment to treatments. The data stemming from the experiments are then used as per Section 2 to estimate the (endogenous) peer effects, the exogenous peer characteristics (contextual) effects, and to identify the nature of the interactions, if any.

4.1. The Baseline treatment

As mentioned in Section 2.1, Baseline subjects play in isolation for a single session. A session comprises 16 periods that last two and a half minutes each. Subjects are asked to mentally multiply as many two-digit and one-digit numbers as possible (*e.g.*, 22×7). The same numbers are used across subjects and sessions to insure homogeneity of treatment. Once the numbers are displayed on the computer screen, subjects enter the answer and, if correct, a new task is displayed. Otherwise, an error message is shown on the screen and another answer must be entered. The screen keeps track of the number of correct answers and the remaining time until the period ends.

At the beginning of each period, a piece rate of either €0.10, €0.50, or €1 is randomly assigned to each subject and displayed on the screen. Payoff in a given period is equal to the number of correct answers times the piece rate. Potential earnings are displayed at the end of each period. When the session ends, the actual payoff corresponds to the earnings of a randomly selected period drawn independently for each subject.

Prior to each session, subjects are paid a fixed randomly selected show-up fee of either €2, €4, or €6. In a standard labor supply model this would correspond to unearned income. This diversity of piece-rates and show-up fees will be useful in the treatments with social information to identify contextual peer effects in accordance with our theory. In addition, subjects are told that performing the multiplications is not compulsory. They are free to

[21] Discriminating between the two amounts to testing the joint equality of the parameter estimates of the exogenous characteristics of the Baseline and Directed Network treatments. Parameter estimates from separate treatments are contrasted with those of the pooled model. Rejection of the pooled model implies rejection of rivalry in favor of conformity.

read the magazines that lay on their desk. These serve as a mimicking device for on-the-job leisure.[22]

Two variants of the Baseline treatment have been implemented. In the first, subjects are not informed that they will be matched to other subjects. In the second, they are. The purpose of the latter variant is to measure the extent to which subjects exhibit self-image concerns.[23] Comparison between the two variants will help us understand differential performances between directed and undirected networks, if any, since in undirected networks, as explained below, the individual's performance is communicated to peers.

4.2. The Directed Network treatment

The set-up of the Directed Network treatment is similar to that of the Baseline treatment. In each of these treatments, subjects are aligned along rows of six seats. But to implement the conditions of our theoretical model the subjects seated at the end of a row are now matched to a single peer from the Baseline, while all others are matched to two peers from the Baseline.[24] Although the Baseline and the Directed Network treatments are separate treatments, Figure 1 depicts the graph of the directed bipartite network as defined in the theory and as implemented in the lab.

Subjects are informed that they are matched to either one or two isolated peers. At the beginning of a session, information on peer characteristics are displayed on the screen. To fit the linear-in-means model developed in the previous section, they includes average age, number of school years, show-up fee, school, gender and relative family wealth (reported on a scale from 1 to 10 – from the 10% poorest to the 10% wealthiest). At the beginning of each period, in addition to own random piece rate, average peer piece rates and performances are displayed on the screen. Subjects are also informed that their peers had to perform the exact same multiplications as themselves, and in the same order. At the end of each period, a summary screen displays own performance, piece rate and earnings, and recalls the average peer piece rates and performances.

As with the Baseline treatment, two variants have been implemented. In the first, subjects are told that their peers participated in a previous session. In the other, subjects are informed that their peers are drawn from the current session but that they started performing the task three minutes in advance. They are further informed that their peers will not

[22] Use of magazines as a leisure activity is common in experimental economics (e.g. Eriksson et al., 2009; Kuhn and Villeval, 2015). The magazines covered a broad range of topics (travel, popular science, *etc.*) to account for preference heterogeneity. Note that the subjects are visually isolated so that browsing through a magazine does not convey any information about the relative difficulty or easiness of a given task. We also use silent keyboards and silent mouses to avoid contamination effects.

[23] The Baseline model developed in the theoretical section focuses on the first variant. Extending the model to the second variant could be achieved by including a dummy variable in equation (1). The parameter of this variable is identified if we exclude session dummies.

[24] As explained below, this spatial configuration parallels that of the Undirected Network treatment although in both the Directed and the Undirected Network treatments subjects are not aware of this.

be communicated any information regarding their own performance and characteristics. In both variants, subjects know that the match will remain the same for the duration of the session. We do not expect the very presence of peers to have any effect on performance since all interactions occur via a computerized interface. The two variants nevertheless serve as a benchmark to isolate the two main differences between the Directed and the Undirect networks: the uni- or bi-directional flow of information and the presence of peers in the room.[25] A comparison between the two variants thus identifies the pure impact of peers being present in the room on own performance. Measuring this potential influence is important when contrasting the Directed Network and Undirected Network treatments.

4.3. The Undirected Network treatment

The set-up of the Undirected and the Directed Network treatments are similar, except that in the former the interactions occur concurrently and information flows between subjects and peers bi-directionally. Information on peer characteristics are displayed on the screen at the beginning of the session. As each period begins, information is provided on own and peer mean piece rates. A session consists of only four *periods* as opposed to sixteen in the Directed Network treatment. On the other hand, each period comprises at most five *rounds*, and as few as required, to achieve convergence to the Nash equilibrium. Hence, at the beginning of a period subjects do not yet know the performance of their peers. At the end of round 1, all subjects are informed about the performance of their peers. In round 2 they can all revise their efforts accordingly. At the end of round 2, subjects are again informed about their peers' revised performance. This process is repeated until the difference in mean network performance between two successive rounds is less than 5%. When this criterion is met, the model is said to have reached a non-cooperative Nash social equilibrium with self-consistent expectations: On average, subjects no longer update their performance when made aware of their peers' performance.[26] A session thus includes a maximum of 20 rounds. The duration of a session is thus approximately similar to that of other treatments and so comparisons between with the latter cannot be contaminated by fatigue.

Convergence assumes a Nash equilibrium has been reached. Yet, the dynamics of our

[25] The Directed Network model developed in the theoretical section focuses on the first variant. Extending the model to the second variant could be achieved by interacting a dummy variable for this variant with peer performance in equation (2).

[26] Subjects were not aware of the convergence rule. If convergence was not reached within 5 rounds, the entire period for the network was omitted from the analysis. The comparison between the Directed and the Undirected Network treatments only makes sense if the quality of the information is the same in both cases. Prior to convergence, too many subjects within the network are still updating their efforts in the face of new information about their peers. Note that upon convergence, expected and contemporaneous expectations are only "almost" equal for two reasons: First, the convergence criterion is not zero. Second, for reasons of tractability, the criterion is applied at the network level, not at the individual level. We applied the same convergence method in Fortin et al. (2007).

model could exhibit cycles or could converge to self-confirming non-Nash equilibria (Fudenberg and Levine, 1993). Unfortunately, the identification and estimation of peer effects in such a case raise complex issues that are beyond the scope of the paper. We thus assume that each network has a unique Nash equilibrium and limit our estimation to periods and networks that have converged. Admittedly, this is a limitation of our framework.[27]

Recall from Section 2.3 that there exists an intimate link between the structure of a network, as described by its graph matrix $\boldsymbol{G}$, and the identification of the endogenous peer effects. In designing a specific network, we have tried to satisfy two separate criteria: (strong) identification and external validity. As for identification, the gender-homogeneous model requires that the matrices $\mathbb{I}, \underline{\mathbb{G}}, \underline{\mathbb{G}}^2$ be linearly independent. From *Proposition 1* the gender-heterogeneous model requires that the matrices $\mathbb{I}^m, \mathbb{I}^f, \underline{\mathbb{G}}^m, \underline{\mathbb{G}}^f, \underline{\mathbb{G}}^{m^2}, \underline{\mathbb{G}}^{f^2}, \underline{\mathbb{G}}^m\underline{\mathbb{G}}^f, \underline{\mathbb{G}}^f\underline{\mathbb{G}}^m$ be linearly independent. The lower the collinearity between these matrices, the more precise the estimated peer effect will be. With respect to external validity, the network should reflect real life interactions between individuals in their work environment.

Based on these two criteria, we have chosen an *undirected line social network*. Each row of six subjects in the laboratory constitutes a network whose graph is depicted in Figure 2. Such a network ensures that at least two subjects are separated by a link of distance 2, a sufficient condition for identification of the peer effect to hold under homogeneity. We also checked that the matrices corresponding to the heterogeneous model were linearly independent. Moreover, the degree of collinearity of the matrices was ascertained by computing the *condition number* of the matrix that results from the vectorization and concatenation of the relevant matrices (Bramoullé et al., 2009).[28] The gender-homogeneous and gender-heterogeneous undirected networks have condition numbers equal to 7.7 and 1.85, respectively, which are considerably lower than 30, and should thus help obtain relatively precise estimates of the peer effects. An undirected network is also likely to have good external validity properties. Indeed, it mimics many work environments in which employees may be paid based on their absolute performance but have the ability to observe their colleagues' pace and performance.

As shown in Figure 2, subjects located at the end of a row are matched to a single peer while all others are matched to two peers. Subjects are not aware of the network structure. They are not told that their peers are their direct neighbors. Figure 3 below sketches our experimental design.

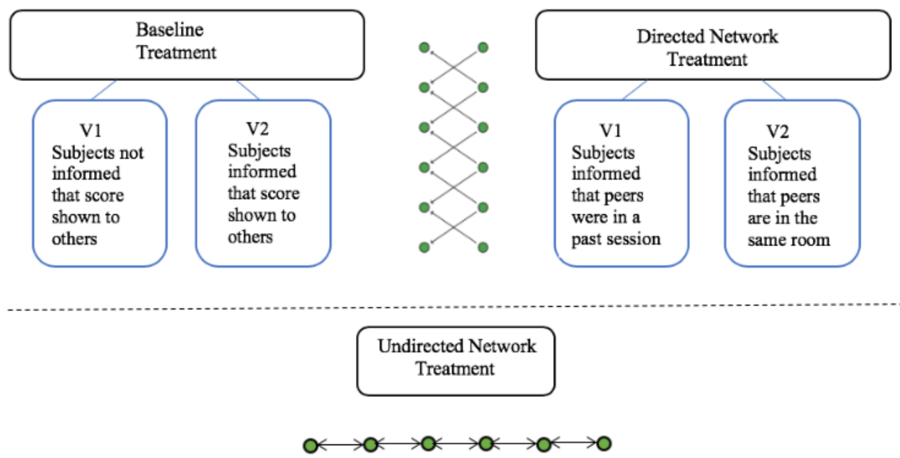
4.4. Experimental procedures

The experiment was programmed using the Z-Tree software (Fischbacher, 2007). All sessions were conducted at GATE-LAB, Lyon, France. Undergraduate students from the local engineering schools (most from École Centrale de Lyon) and business schools (most

[27] We thank a referee for having raised this point.

[28] The condition number of a matrix $\boldsymbol{A}'\boldsymbol{A}$ is given by the square root of the ratio of its maximum and minimum eigenvalues. A condition number above 30 is indicative of serious collinearity.

Figure 3: Experimental Design



Note: In the Baseline treatment, N=84 (Variant 1: N=36; Variant 2: N=48). In the Directed Network treatment, N=87 (Variant 1: N=39; Variant 2: N=48). In the Undirected Network treatment, N=204.

from EMLyon Business school) were invited via the ORSEE software (Greiner, 2015). As outlined in Table A2 of Appendix A, a total of 375 subjects took part in the experiment, in one of 24 sessions. We made sure we had almost as many females as males in each treatment. For the Baseline treatment, we organized 10 sessions with 84 subjects (2 sessions with 36 subjects in isolation, and 8 sessions with 48 subjects in the variant with information), of which 39 are females. In the Directed Network treatment, we organized 11 sessions with 87 subjects (3 sessions with 39 subjects in the variant without the presence of peers, and 8 sessions with 48 subjects in the variant with the presence of peers from the Baseline), of which 42 are females. Note that we implemented the second variant of the Baseline and the Directed Network treatments in the same sessions: in each of these eight sessions, we had 6 subjects playing the Baseline, knowing that their performance would be reported to other subjects, and 6 subjects playing the Directed Network treatment, knowing that their peers were present in the session. Finally, 11 sessions of the Undirected Network treatment were organized that involved over 204 subjects (102 of each gender). Subjects in the Undirected Network treatment are more numerous since each session provides a maximum of four observations per subject since we only use the round when convergence has been achieved.

Upon arrival in the laboratory, subjects drew a ticket from an opaque bag assigning them to a specific computer terminal. The instructions describing the task, the payment scheme and the available set of information were distributed and read aloud (see Appendices B, C and D). Next we used a questionnaire to assess the subjects' understanding of the rules. Answers were verified individually. Subjects then had to report their age, gender, school, number of years of study, and belief about the wealth of their family relative to that of the other students of the same school. This was followed by a practice period of two and a half minutes to get familiarized with the task, after which the game started.

Once the final period ended, subjects were told individually which period (or which round in the Undirected Network treatment) was randomly selected for payment along with their earnings. They next had to complete an exit survey. A session lasted about 60 minutes and subjects earned on average €13.27 (standard deviation = €8.99), including a €4.13 average show-up fee (S.D. = €1.63).

5. Results

We start by presenting descriptive statistics on the sample of subjects and the main parameters of the treatments. We then turn to the econometric results.

5.1. Summary statistics

Table 1 reports the means and standard deviations of the main variables used in the econometric analysis. The statistics are presented separately for the three main treatments. The three rightmost columns of the table report the p-value of two-tailed test statistics of equality between the Directed Network/Baseline treatments, the Undirected Network/Baseline treatments and the Directed /Undirected Network treatments, respectively (Mann-Whitney tests for performance, fixed income, piece rate, age, relative wealth, and t-tests for the proportion of males and students from the engineering school).[29]

According to the p-values in Table 1, most variables are balanced across the three treatments, including the gender variable. There are, however, small differences for some treatments between the subjects' age and the peers' age, relative family wealth, and engineering school.[30]

The bottom panel of these tables focuses on the parameters and the outcomes of the different treatments. Not surprisingly, there is no significant difference in the mean piece rates across treatments and variants. The mean performance is not significantly different either across variants and treatments, although the comparison between the Directed Network and the Undirected Network treatments reveals a marginally significant difference.[31]

[29] Table A1 of Appendix A reports the same statistics for the two variants of the Baseline and the Directed Network treatments. As with the two main treatments, there are few differences between the subjects of the two variants.

[30] Subjects in the Directed Network and Undirected Network treatments are slightly older than those of the Baseline, whereas subjects in the Directed Network treatment report the lowest relative family wealth. Subjects in the Undirected Network treatment are paired with slightly older peers than those in the Directed Network treatment. This is because the latter are paired with individuals from the Baseline treatment who happen to be younger. Students from the ECL engineering school represent a lower proportion of the subjects in the Directed Network treatment than in the other treatments.

[31] We also investigated the number of trials and errors and found that the average success rate is pretty high (for example, 84.58% (S.D.=13.67) in the Baseline treatment), suggesting that the task was relatively

5.2. Estimation Strategy

The main purpose of the paper is to investigate gender-specific responses to peer effects in various network environments. Our empirical strategy consists first in estimating performance in the Baseline, Directed Network and Undirected Network treatments under the assumption that males and females subjects respond similarly to variations in peer performances and in the other explanatory variables (Gender-Homogeneous models). Under this assumption, we also present the estimates when the Baseline and the Directed Network treatments are pooled. This allows us to provide a test of pure rivalry and to obtain more efficient estimates as long as this hypothesis is not rejected. Next, we contrast our estimates to those obtained from relaxing the assumption of equality in gender coefficients (Gender-Heterogeneous models).

In principle, testing the null hypothesis of equal gender-specific peer effects should give the same result for both the Directed Network and Undirected Network treatments. Yet, it can be argued that the Undirected Network treatment is qualitatively different from the Baseline and Directed Network treatments. This is because playing simultaneously and knowing that one's performance is revealed to others may entail more competitive rivalry between subjects and their peers. Indeed, unlike in the original Baseline and Directed Network treatments, in the Undirected Network treatment the subject's performance is averaged with that of another subject and shown in real time to peers who are physically present in the same session. Subjects may thus behave differently out of "pure image" concerns. As stressed above, these potential influences can be inferred indirectly by estimating the two variants of the Baseline and Directed Network treatments (see variants V1 and V2 in Figure 3).

5.3. Estimation Results

As stressed above, the main focus of the paper is on gender-specific responses to peer effects. Recall that these effects may arise through two channels: An *endogenous* peer effect and so-called *contextual* peer effects. Our experiments were designed so that we could further discriminate between two mechanisms that could potentially give rise to the endogenous peer effect: pure rivalry and conformity. Our discussion of the results is organized accordingly. We first state our findings with respect to the endogenous effects. We next focus on the contextual effects. As these pertain to the impact of the observable characteristics of one's peers on own performance, we also discuss how one's own characteristics may also influence performance. We begin by presenting the results from the Gender-Homogeneous models (Table 2) and we next turn to those of the Gender-Heterogeneous models (Table 3).

easy. The success rate increases significantly over time while the number of errors is stable, which is compatible with learning but not with fatigue. We found no significant difference across gender in terms of performance, errors and success rate. For lack of space, and considering the quantitatively relatively small effect of time on performance and success, all the analyses reported in the paper are based upon the number of correct answers.

5.3.1. Gender-Homogeneous Peer Effects

Result G-H 1: *a) Individual performance is positively linked to peer performance in the Directed Network and Undirected Network treatments;*[32] *b) The competitive rivalry mechanism through which peer effects influence individual performance is not rejected while the conformity mechanism is rejected. c) Knowing own performance will be communicated to future subjects has no impact; d) Knowing peers are physically present in same session has no impact. e) Individual and peer performances are linearly related.*

Support for Result G-H 1. The most noteworthy result in Table 2 is that peer performance enhances own performance significantly in all the treatments. With session fixed effects (which are jointly significant except in the pooled specification), the parameter estimate is equal to 0.209 in the Directed Network model, 0.198 in the pooled model, and 0.051 in the Undirected Network model (absent fixed effects, we get 0.176, 0.179 and 0.107, respectively). The estimates are statistically significant at the 1% level in almost all models. The former can (approximately) be interpreted as mean peer performance elasticities.[33] The peer effects are much smaller in the Undirected Network models than in the pooled and Directed Network ones. We delay a discussion on this crucial result to the section on heterogeneous models.

Comparing the exogenous characteristics in the baseline and the Directed Network models using the pooled model allows us to test the rivalry mechanism hypothesis. This test is not rejected at the 5% level when the session fixed effects (which are not jointly significant, with a p-value = 0.134 in the pooled model) are excluded. More specifically, the p-value of the pooled model test is 0.068 (see column (5), in the bottom panel of Table 2).

The peer effect holds regardless of whether peers are present or not in the same session, since the parameter estimates associated with *Presence*×*Peer performance* effect is never found to be statistically significant. Likewise, own performance is not related to the "pure image" concern since the parameter estimates of the *Observability* variable is never statistically significant either. This finding does not replicate Mas and Moretti (2009), but is consistent with Georganas et al. (2015) who found that, under piece rate, being observed does not affect performance while observing others does.

It has been argued that estimating "average" peer effects may yield misleading results if individual and peer performances are nonlinearly related (Sacerdote, 2011; Tincani, 2015). For instance, subjects may feel competitive rivalry mostly when they are doing as well as

[32] The tests performed are one-tailed tests as we assume that the alternative hypothesis is a positive peer effect. For all the other effects, two-tailed tests are used.

[33] Note that most of our estimates are quite close to those previously found in the literature: Falk and Ichino (2006) find a 1.4% increase in individual performance following a 10% increase in peer productivity; Mas and Moretti (2009) and Lindquist et al. (2015) estimate a 1.7% increase (see Herbst and Mas, 2015 for a survey). These estimates are, however, not strictly comparable since the work environment varies considerably across studies.

their peers, but not so when they do much better or much worse.[34] We investigate the link between the two through a series of random effects quantile regressions (see Table A.3 of Appendix A). Estimation results using the Directed Network treatment and the Gender-Homogeneous model indicate that the same parameter estimates are statistically significant across quantiles. In addition, a standard random effects regression (column *RE*) yields very similar results to the 50th percentile regression (column *Q(0.5)*). The performance peer effect is only statistically significant for the 50th and 90th percentiles. A Wald test on the equality of the peer performance parameter estimates across quantiles yields a p-value equals to 0.369. These results provide evidence that individual and peer performances are linearly related.

Result G-H 2: *Contextual peer effects have little impact on individual performance in any type of network.*

Support for Result G-H 2. Table 2 indicates that only peer mean age is statistically significant (p-value < 0.05) in the Directed Network model. The corresponding parameter estimate in the pooled model (with no session fixed effects) is not significant.[35] Its negative sign when significant suggests that younger peers may induce subjects to increase effort so as to remain competitive. In the Undirected Network treatment, only being matched to someone from the ECL engineering school has an impact on own performance. Having more peers from this elite school may discourage subjects with weaker mathematical backgrounds. That this effect is only significant in the simultaneous networks may indicate that this context enhances the sense of competition among subjects and peers. Interestingly, the gender composition of the peer group has no impact on own performance.

A number of individual variables have significant impact on performance. A higher piece rate significantly increases effort in all models except in the Undirected Network specification with session fixed effects and are of similar magnitude. With no fixed effects, the parameter estimates indicate that increasing the piece rate twofold increases performance by as much as 0.608 units in the pooled model (column (5)) and by 0.552 units in the simultaneous model (column (7)). As expected, attending the ECL engineering school is also associated with increased performance. Older individuals perform better only in the Undirected Network treatment. The fixed income parameter estimate is positive[36] in the Undirected Network treatment and not significant in the Directed Network treatment when there are fixed effects. Finally, in all models, performance increases with the number of periods, which may suggest that the learning effect dominates the fatigue effect. The larger effect in the Undirected Network model results from the fact that each period consists of

[34] We thank a referee for having raised this point.

[35] The pooled sample must necessarily yield estimates that correspond to some average of the Baseline and the Directed Network treatments.

[36] This could be due to a gift effect on performance.

several rounds.[37]

All in all, the parameter estimates are relatively robust across all specifications. In all treatments mean peer performance increases individual effort and individuals respond to financial incentives. The only somewhat surprising result concerns the smaller impact of peer performance in the Undirected Network model. We show how the estimates of the gender-specific models explain this finding.

5.3.2. Gender-Heterogeneous Peer Effects

The results discussed up to now focus on the homogeneous models. These are nevertheless subject to an important *caveat*. Indeed, based on Wald tests, these models are not rejected in the baseline specifications, and in the Directed Network and the pooled ones (when session fixed effects are not accounted for). However, they are rejected in the Directed Network and the pooled specifications (with session fixed effects), and in the Undirected Network specifications.[38] Given the outcomes of these tests, it is important to turn to the results from the more general heterogeneous models.

Result G-Het 1: *a) Peer effects differ by gender: Males respond positively to peer performance in all network configurations whereas females respond positively in the directed networks, but not so in the undirected networks; b) Both female and male performances are insensitive to the fact that own performance is communicated to future subjects; c) Males and females are indifferent to having peers in the same session. d) In the absence of peer effects, the competitive rivalry mechanism through which peer effects influence individual performance is not rejected while the conformity mechanism is rejected.*

Support for Result G-Het 1. Table 3 shows that peer effects vary strongly across gender. In the absence of session fixed effects, the responsiveness of male subjects to peer performance increases from the Directed Network and pooled specifications (0.179, 0.179, respectively) to the Undirected Network one (0.274). When fixed effects are accounted for, the results show that males slightly reduce own performances as we move from Directed Network, pooled and Undirected Network specifications (0.261, 0.227, 0.172, respectively). In contrast, the peer effect of female subjects strongly decreases as we move from the Directed Network to the Undirected Network treatments (0.183, 0.179 and -0.057, respectively, without fixed effects, and 0.187, 0.193 and -0.049, respectively, with fixed effects).[39] In the Undirected Network treatment, the estimates associated with peer performance is negative for females, albeit not statistically significant. In the other treatments, the peer performance estimates are significant at the 1% level, irrespective of gender.

[37] The estimation uses periods and not rounds because the number of rounds is not exogenous, as it depends on convergence across the network.

[38] The p-value associated with these Gender Homogeneity tests is provided in the bottom panel of Table 2.

[39] For males and females, fixed effects are jointly significant for all specifications except for the pooled one.

What may explain the fact that female subjects are indifferent to peer performance in the undirected networks only? Close inspection of the parameter estimates reveals an interesting empirical regularity: male and female subjects behave similarly whenever information about own or peer performances flows one way. Indeed, in the Baseline treatment, male and female subjects do not react to having their performances communicated to future subjects. Likewise, male and female subjects in the Directed Network and Pooled treatments are indifferent to having their peers in the same session.These results rule out the so-called "pure image" and "presence" effects alluded to above. It must be, then, that female subjects perceive the undirected network environment, with its two-way interactive flow of information, differently from their male counterparts. Male performances, on the other hand, are fairly constant across network configurations.

To explore this issue, it is important to analyse which mechanism better explains peer effects under gender heterogeneity. Based on the pooled model with no fixed effects,[40] we do not reject the joint equality of individual characteristics in the baseline and the Directed Network models. More specifically, the p-value of the pooled model test is 0.624 for male subjects and 0.311 for female subjects (see column (5), in the bottom panel of Table 3). These results are consistent with the hypothesis that peer effects influence individual performance through a competitive rivalry channel and not through a conformity mechanism.

We are thus led to infer that females, as opposed to males, perceive the undirected networks as a different work environment than that of directed networks. We contend that they may possibly perceive it as being more competitive, whereas they may view their peers' performance in the directed networks as a simple reference point in terms of motivational goal settings. It is now well-established that females, unlike males, tend to underperform in competitive environments and to shy away from competition (e.g. Gneezy et al., 2003; Niederle and Vesterlund, 2007). If females do indeed perceive the undirected networks as a more competitive environment, they may be led to ignore their peers' performance or to respond by decreasing their own effort. If this interpretation is correct, our results would suggest that more competitive non-monetary or informational incentives may also have a discouraging effect on their efforts.

Result G-Het 2: *The contextual peer effects vary across genders mostly in the Undirected Network treatment.*

Support for Result G-Het 2. Table 3 shows that peer contextual effects vary across gender in the Undirected Network specification. In particular, females react negatively to having more males among their peers, whereas no such effect is observed for males. In addition, the proportion of peers from the ECL engineering school has no impact on female performances but a large and negative one on males. Males appear demotivated when matched with potentially more able individuals. Mean peer age also affects male and female subjects differently, having a positive effect on female performance and a negative

[40] For both male and female subjects, fixed effects are jointly rejected at the 5% level in the pooled model.

one on male performance. Finally, while females appear to be indifferent to their peers' mean wage in all network configurations, males tend to respond negatively in the pooled configuration.

Individual effects also vary considerably across gender. As found in the psychology literature (Torrubia et al., 2001; Li et al., 2007)[41] and in Kuhn and Villeval (2015), but in contrast to Paarsch and Shearer (2007) and to the recent meta-analysis of Bandiera et al. (2016), males appear to be more sensitive to the level of financial incentives. Indeed, in nearly all specifications except in the Undirected Network models, their performances are intimately linked to the piece rate. For females, while the parameter estimate is statistically significant in the baseline and the pooled specifications, it is much smaller than that of males in all cases. Attending the ECL engineering school is generally associated with a larger performance for both males and females. But female attendees always outperform the other females, regardless of the treatment, whereas male attendees outperform other males only in the Pooled and the Undirected Network treatments. Finally, note that the evolution of effort over time also differs by gender in the Undirected Network treatment.

Overall, these findings indicate that females react differently than males to information about their peers in the undirected networks. Gender differences in contextual peer effects are also consistent with the undirected network setting being perceived as more competitive by female subjects. It could be argued, following Möbius et al. (2011), that females are more "ego-defensive", *i.e.* less confident and more conservative updaters, to exhibit more aversion toward relative performances.

6. Conclusion

Recently, a growing literature has attempted to investigate the link between own and peer performances in the labor market. However, few studies have reported gender-specific results. In this paper, our contribution to this research area is threefold. First, we explicitly focus on gender-specific responses of own performance to peer performances. Second, we investigate these within various network configurations rather than the more common group framework. To our knowledge, this is the first paper that compares the importance of peer effects at work in different work environments. More specifically, we develop two linear-in-means social interactions models with gender heterogeneity. In the first, the networks are structured such that the information on wages and performances flows one-way from the peer to the subject (Directed Network model). In the second, information flows both ways (Undirected Network model). Gender-specific peer effects can be identified in both models. Our third contribution is to explore the mechanisms (in particular, competitive rivalry *vs.* conformity) through which peer effects influence individual performances in our framework.

Our analysis has unearthed important results about peer and gender effects in a network

[41] Possibly for evolutionary reasons (Browne, 2002; Kanasawa, 2005).

setting. On the whole, we find that individuals generally respond to financial incentives and are sensitive to information about their peers. Yet, there are important differences as regards gender responses to social interactions. While males increase their effort when learning about the productivity of their peers, irrespective of the network structure, females behave entirely differently in various network settings. In a directed network setting, they are sensitive to the productivity of their peers, although to a slightly lesser extent than males. But in an undirected network setting, they behave as if information on peer performances was irrelevant and work almost as if in isolation. In addition, not only do the endogenous peer effects differ across genders, so do the contextual peer effects. Indeed, females are indifferent to their peers' wage regardless of the network configuration; in contrast, males adjust their effort to their peers' wages, at least in the pooled networks.

Our exploration of the channels through which peer effects affect performances helps explain these results. Our econometric tests based on Boucher and Fortin (2016) show that competitive rivalry is a more likely cause of peer effects than conformity. From these results, we argue that female subjects, as opposed to males, perceive the undirected networks, where information flow both ways, differently from the directed networks. Since a number of studies have shown that females tend to shy away from competition, a possible interpretation is that they see the undirect networks as constituting a more competitive environment than the directed networks. Informational variants were also in our experiment to investigate whether differences between the directed and undirected networks are due to having one's performance scrutinized by a peer, albeit in an anonymous fashion. Our results are consistent with those of Georganas et al. (2015) in that only the observer changes his effort, not the observee, and they differ from those of Mas and Moretti (2009). In addition, our data show no evidence of any impact of having one's peer in the lab on individual performances.

Empirical evidence on peer effects at work is relatively scant. This is partly because obtaining proper estimates in real-life settings raises notoriously difficult identification problems. Indeed, social networks at work are likely to be endogenous and disentangling performance from contextual peer effects is difficult when workers interact in groups and that the average size of these groups is large. In this paper, we argue that a carefully designed laboratory experiment can help solve this problem for two reasons. First, individual reference groups can be determined exogenously by the experimentalist. Second, the structure of the network can be designed in a manner that guarantees identification of all social interactions within the linear-in-means model. van Veldhuizen et al. (2018) stress the many advantages of using such a controlled environment for the study of social interactions. We acknowledge, however, that laboratory experiments also have their own limitations. In our particular case, networks are formed exogenously and the task subjects are asked to perform is artificial. Notwithstanding this, there is now widespread agreement about the external qualitative validity of laboratory experiments (Fréchette and Schotter, 2014). Importantly, in their recent meta-analysis Herbst and Mas (2015) have shown that the laboratory estimates of peer effects on productivity are similar to those obtained from field experiments.

Keeping in mind the aforementioned caveats, our results may have a number of implications for real workplace arrangements. Indeed, the existing literature has already shown that providing feedback on peer performances may increase effort under certain conditions. We show that these conditions include the mode of work organization (network type) and the gender composition of the workforce. In a predominantly female environment, it may be preferable to organize the networks such that the information on performance flows one way. In a predominantly male environment, the network structure matters little.

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Table 1: Comparison between the Baseline, Directed Network and Undirected Network treatments

Treatments	Baseline (V1+V2)		Directed Network (V1+V2)		Undirected Network		Dir/B	Und/B	Dir/Und
	Average	S.E.	Average	S.E.	Average	S.E.			
Males (%)	46.43	50.17	48.28	50.26	50.00	50.12	0.810	0.530	0.758
Age	21.08	1.71	22.99	6.19	21.85	2.98	0.005	0.015	0.221
Relative wealth	4.96	2.15	4.66	1.88	5.12	1.85	0.180	0.738	0.031
Central Engineering School (%)	27.38	4.86	16.09	36.96	27.94	44.98	0.074	0.913	0.017
Endowment (show up fee)	4.29	1.52	3.98	1.82	4.13	1.60	0.266	0.458	0.514
Male peers (%)			45.40	41.51	50.00	42.96			0.333
Age of peers			20.97	1.55	21.68	2.04			0.001
Relative wealth of peers			5.03	1.69	5.05	1.53			0.977
Peers in Central Engineering School (%)			22.99	32.17	28.19	38.79			0.224
Endowment of peers (show-up fee)			4.17	1.18	4.12	1.35			0.847
Number of individuals	84		87		204				
Piece-rate	0.54	0.38	0.54	0.37	0.53	0.37	0.898	0.947	0.994
Piece-rate of peers			0.54	0.31	0.54	0.29			0.728
Performance	18.20	7.39	17.84	8.78	18.95	7.58	0.332	0.564	0.101
Performance of peers			17.96	5.93	18.81	6.22			0.319
Number of observations	1344		1392		510				

Notes: In the Baseline, N=84 (Variant 1: N=36; Variant 2: N=48). In the Directed Network treatment, N=87 (Variant 1: N=39; Variant 2: N=48). In the Undirected Network treatment, N=204. Columns 7 to 9 report the p-values of various non-parametric tests, all two-tailed. Column 7 compares the Directed Network and the Baseline treatments; column (8) compares the Undirected Network and the Baseline treatments; column (9) compares the Directed Network and the Undirected Network treatments. In the non-parametric statistics, each individual (and one mean value for observations regarding the same individual) gives one independent observation. For the Undirected Network treatment, we only consider rounds in which convergence has been achieved. For age, endowment, piece rate, wealth, score, we use Mann-Whitney tests. For gender and Central School, we use two-sample t-tests with equal variances.

Table 2: Gender-Homogeneous Model

	Baseline†		Directed Network†		Pooled†		Undirected Network‡	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Observability	1.358				1.473			
	(1.343)				(1.373)			
Peer performance			0.176***	0.209***	0.179***	0.198***	0.107***	0.051*
			(0.044)	(0.049)	(0.045)	(0.049)	(0.035)	(0.038)
Presence × Peer performance			-0.038	-0.091	-0.044	-0.083		
			(0.069)	(0.089)	(0.066)	(0.082)		
Peer characteristics								
Wage (log)			-0.028	-0.03	-0.03	-0.03	0.486	0.466
			(0.149)	(0.149)	(0.148)	(0.148)	(0.350)	(0.399)
Wealth			0.189	0.057	0.632	0.629	0.061	0.125
			(0.4823)	(0.464)	(0.441)	(0.452)	(0.185)	(0.203)
Age			-1.105**	-1.259***	-0.266	-0.358*	0.12	0.05
			(0.489)	(0.486)	(0.190)	(0.196)	(0.117)	(0.191)
Fixed Income			-0.534	-0.29	-0.207	-0.057	0.163	0.102
			(0.719)	(0.822)	(0.772)	(0.777)	(0.229)	(0.231)
ECL engineering school			3.383	3.346	2.079	2.488	-1.633***	-2.158**
			(2.432)	(2.47)	(2.588)	(2.648)	(0.698)	(0.93)
Proportion of males			0.652	0.719	1.573	2.447	-0.618	-0.139
			(2.067)	(1.965)	(2.032)	(1.936)	(0.703)	(1.126)
Individual characteristics								
Wage (log)	0.573***	0.571***	0.643***	0.642***	0.608***	0.607***	0.55*	0.552
	(0.183)	(0.184)	(0.225)	(0.225)	(0.144)	(0.145)	(0.312)	(0.34)
Wealth	-0.107	-0.098	0.705	0.718	0.209	0.2	0.072	0.074
	(0.338)	(0.321)	(0.537)	(0.516)	(0.297)	(0.31)	(0.165)	(0.196)
Age	0.125	0.134	-0.041	0.061	-0.016	0.043	0.35***	0.313**
	(0.349)	(0.314)	(0.121)	(0.139)	(0.114)	(0.125)	(0.09)	(0.128)
Fixed Income	0.342	0.367	-0.759*	-0.613	-0.299	-0.253	0.362*	0.34*
	(0.407)	(0.412)	(0.413)	(0.421)	(0.307)	(0.32)	(0.188)	(0.188)
ECL engineering school	2.58*	3.216**	4.747**	5.756**	3.38***	4.043***	6.479***	5.977***
	(1.59)	(1.587)	(2.293)	(2.354)	(1.327)	(1.349)	(0.758)	(0.911)
Period	0.247***	0.247***	0.249***	0.248***	0.248***	0.248***	0.98***	1.097**
	(0.039)	(0.039)	(0.036)	(0.036)	(0.026)	(0.026)	(0.341)	(0.427)
Intercept	11.617	10.546	36.858***	31.919**	15.589***	12.56***	1.483	1.744
	(8.939)	(8.277)	(11.635)	(14.337)	(3.511)	(3.996)	(1.944)	(6.069)
Session Fixed Effects	No	Yes	No	Yes	No	Yes	No	Yes
N	1344	1344	1392	1392	2736	2736	510	510
Log likelihood							-3047	-3024
Session Fixed Effects =0 (*p-value*)		0.000		0.0152		0.1341		0.000
Pooled Model Test (*p-value*)					0.0685	0.0007		
Gender Homogeneity Model Test (*p-value*)	0.4853	0.7446	0.455	0.0000	0.1770	0.0487	0.021	0.000
Peers' performance Gender Homogeneity Test (*p-value*)			0.9382	0.5155	0.9944	0.7388	0.0000	0.0027

†Random effects with panel clustered S.E. ‡Maximum likelihood wih panel clustered S.E.
***Indicates 1% significance level, **Indicates 5% significance level, *Indicates 10% significance level.

Table 3: Gender-Heterogeneous Models (Male Variables)

	Baseline†		Directed Network†		Pooled†		Undirected Network‡	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Observability	1.386				0.922			
	(2.318)				(2.195)			
Peer performance			0.179***	0.261***	0.179***	0.227***	0.274***	0.172***
			(0.074)	(0.075)	(0.072)	(0.077)	(0.081)	(0.072)
Presence ×Peer performance			-0.012	-0.139	-0.002	-0.083		
			(0.079)	(0.09)	(0.078)	(0.088)		
Peer characteristics								
Wage (log)			-0.289	-0.303	-0.3**	-0.306*	0.695	0.751
			(0.190)	(0.190)	(0.185)	(0.184)	(0.585)	(0.532)
Wealth			-0.152	0.206	0.349	-0.119	-0.062	0.016
			(0.686)	(0.519)	(0.659)	(0.608)	(0.289)	(0.276)
Age			-1.436**	0.003	-0.372	-0.284	-0.44**	-0.798***
			(0.737)	(0.664)	(0.286)	(0.226)	(0.22)	(0.195)
Fixed income			-0.388	1.410	0.455	0.453	0.262	0.22
			(1.636)	(1.133)	(1.327)	(0.964)	(0.361)	(0.428)
ECL engineering school			4.967	4.080	5.211	2.938	-4.999**	-6.759***
			(4.416)	(4.117)	(4.380)	(4.074)	(2.423)	(2.504)
Proportion of males			1.392	2.058	2.411	3.584	1.654	2.33
			(3.989)	(2.669)	(3.529)	(2.764)	(1.727)	(2.86)
Individual characteristics								
Wage (log)	0.873***	0.872***	1.069***	1.071***	0.973***	0.972***	0.728	0.687
	(0.339)	(0.342)	(0.380)	(0.381)	(0.253)	(0.254)	(0.475)	(0.485)
Wealth	-0.162	-0.356	0.624	1.129*	0.173	0.235	-0.098	0.022
	(0.442)	(0.414)	(0.941)	(0.639)	(0.488)	(0.454)	(0.219)	(0.251)
Age	0.029	0.106	0.000	0.715***	-0.024	0.299	0.324***	0.228
	(0.428)	(0.368)	(0.360)	(0.253)	(0.247)	(0.254)	(0.108)	(0.158)
Fixed income	-0.177	-0.238	-1.023	-0.642	-0.606	-0.386	0.608**	0.549*
	(0.687)	(0.646)	(0.708)	(0.538)	(0.487)	(0.453)	(0.302)	(0.309)
ECL engineering school	2.244	2.105	4.243	4.429	3.059*	3.097*	6.237***	5.409***
	(2.303)	(2.637)	(3.324)	(3.134)	(1.869)	(1.913)	(0.88)	(1.197)
Period	0.209***	0.209***	0.228***	0.225***	0.218***	0.217***	0.41	0.679
	(0.072)	(0.072)	(0.059)	(0.058)	(0.046)	(0.046)	(0.492)	(0.516)
Intercept	16.456	15.996	45.472*	-21.217	17.769***	7.645	13.145**	20.301***
	(11.789)	(10.463)	(27.097)	(21.304)	(7.199)	(7.628)	(5.453)	(4.97)
Session Fixed Effects	No	Yes	No	Yes	No	Yes	No	Yes
N	624	624	672	672	1296	1296		
Session Fixed Effects =0 (*p-value*)		0.000		0.000		0.0548		0.001
Pooled Model Test (*p-value*)					0.624	0.000		

†Random effects with panel clustered S.E. ‡Maximum likelihood wih panel clustered S.E.
***Indicates 1% significance level, **Indicates 5% significance level, *Indicates 10% significance level.

Table 3 Continued: Gender-Heterogenous Models (Female Variables)

	Baseline†		Directed Network†		Pooled†		Undirected Network‡	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Observability	2.17				2.453			
	(2.15)				(1.843)			
Peer performance			0.183***	0.187***	0.179***	0.193***	-0.057	-0.049
			(0.058)	(0.067)	(0.059)	(0.065)	(0.058)	(0.067)
Presence × Peer performance			-0.082	-0.09	-0.077	-0.112		
			(0.113)	(0.155)	(0.107)	(0.139)		
Peer characteristics								
Wage (log)			0.224	0.221	0.226	0.223	0.4	0.499
			(0.225)	(0.225)	(0.223)	(0.222)	(0.472)	(0.659)
Wealth			0.845	0.806	0.956**	0.917**	-0.063	-0.092
			(0.532)	(0.624)	(0.477)	(0.484)	(0.276)	(0.409)
Age			-0.174	0.168	-0.158	-0.259	0.440**	0.719***
			(0.711)	(0.671)	(0.273)	(0.286)	(0.184)	(0.197)
Fixed Income			-1.139	-0.683	-0.975	-0.853	0.151	0.289
			(0.796)	(1.068)	(0.794)	(0.940)	(0.276)	(0.290)
ECL engineering school			0.908	-0.024	0.432	1.834	0.462	0.953
			(3.366)	(3.303)	(3.309)	(3.247)	(1.018)	(1.852)
Proportion of males			0.848	0.193	1.237	1.955	-2.761*	-2.974*
			(1.992)	(2.291)	(2.047)	(2.204)	(1.562)	(1.681)
Individual characteristics								
Wage (log)	0.306**	0.306*	0.24	0.239	0.271**	0.268**	0.422	0.24
	(0.162)	(0.16)	(0.236)	(0.235)	(0.141)	(0.141)	(0.442)	(0.548)
Wealth	-0.109	0.223	0.968**	0.96	0.323	0.228	0.238	0.271
	(0.528)	(0.75)	(0.505)	(0.636)	(0.367)	(0.496)	(0.272)	(0.294)
Age	-0.159	-0.253	-0.083	-0.017	-0.044	-0.018	0.373	0.333
	(0.736)	(0.751)	(0.134)	(0.127)	(0.141)	(0.129)	(0.231)	(0.208)
Fixed Income	0.906**	1.249**	-0.505	-0.597	0.02	0.074	0.274	0.482*
	(0.479)	(0.545)	(0.478)	(0.472)	(0.355)	(0.427)	(0.236)	(0.28)
ECL engineering school	6.857***	7.466***	5.837**	5.745*	5.956***	6.538***	6.238***	6.277***
	(2.332)	(2.36)	(2.561)	(3.225)	(1.586)	(2.002)	(1.817)	(1.737)
Period	0.282***	0.283***	0.282***	0.282***	0.282***	0.282***	1.665***	1.624**
	(0.035)	(0.036)	(0.04)	(0.041)	(0.026)	(0.026)	(0.527)	(0.708)
Intercept	14.305	11.146	14.913	3.908	13.283***	12.143***	-4.067	-12.741***
	(16.476)	(18.189)	(13.382)	(16.403)	(3.982)	(4.622)	(5.038)	(4.04)
Session Fixed Effects	No	Yes	No	Yes	No	Yes	No	Yes
N	720	720	720	720	1440	1440	510	510
Log likelihood							-3018	-2964
Session Fixed Effects =0 (*p-value*)		0.0158		0.0000		0.6314		0.001
Pooled Model Test (*p-value*)					0.3111	0.0969		

†Random effects with panel clustered S.E. ‡Maximum likelihood wih panel clustered S.E.
***Indicates 1% significance level, **Indicates 5% significance level, *Indicates 10% significance level.

Supplemental Material: Web Appendix

A. Additional Tables

Table A1: Comparison between the two variants of the Baseline and the Directed Network treatments

Treatments	Baseline-V1		Baseline-V2		V1/V2	Directed Network-V1		Directed Network-V2		V1/V2
	Average	S.E.	Average	S.E.		Average	S.E.	Average	S.E.	
Males (%)	52.78	50.63	41.67	49.82	0.318	51.28	50.64	45.83	50.35	0.618
Age	20.78	1.77	21.31	1.64	0.049	23.38	5.21	22.67	6.92	0.153
Relative wealth	5.19	1.85	4.79	2.35	0.394	4.49	1.86	4.79	1.90	0.420
Central Engineering School (%)	27.78	45.43	27.08	44.91	0.944	28.21	45.59	6.25	24.46	0.005
Endowment (show-up fee)	4.22	1.49	4.33	1.56	0.713	3.79	1.88	4.12	1.77	0.397
Male peers (%)						51.28	43.66	40.62	39.49	0.236
Age of peers						20.82	1.79	21.08	1.33	0.121
Relative wealth of peers						5.26	1.51	4.85	1.81	0.213
Peers in Central Engineering School (%)						28.21	37.69	18.75	26.55	0.174
Endowment of peers (show-up fee)						4.08	1.16	4.25	1.21	0.561
Number of individuals	36		48			39		48		
Piece-rate	0.52	0.38	0.54	0.38	0.382	0.54	0.38	0.37	0.37	0.510
Piece-rate of peers						0.53	0.31	0.55	0.31	0.149
Performance	17.33	7.85	18.85	6.94	0.228	18.12	8.92	17.61	8.68	0.695
Performance of peers						17.34	6.21	18.46	5.64	0.481
Number of observations	576		768			624		768		

Table A2: Characteristics of the experimental sessions

Session	Number of subjects	% of females	Treatments	Information on peers' performance	Presence of peers in the session	Performance visible to others in the session
1	18	50	Baseline - V1	-	-	No
2	18	44.5	Baseline - V1	-	-	No
3	18	55.5	Directed Network - V1	Yes	No	No
4	12	41.5	Directed Network - V1	Yes	No	No
5	9	44.5	Directed Network - V1	Yes	No	No
6	18	50	Undirected Network	Yes	Yes	Yes
7	18	33.3	Undirected Network	Yes	Yes	Yes
8	12	50	Undirected Network	Yes	Yes	Yes
9	12	50	Undirected Network	Yes	Yes	Yes
10	18	55.5	Undirected Network	Yes	Yes	Yes
11	18	72.2	Undirected Network	Yes	Yes	Yes
12	18	55.5	Undirected Network	Yes	Yes	Yes
13	6	66.7	Baseline - V2	-	-	Yes
	6	50	Directed Network - V2	Yes	Yes	No
14	6	33.3	Baseline - V2	-	-	Yes
	6	33.3	Directed Network - V2	Yes	Yes	No
15	6	50	Baseline - V2	-	-	Yes
	6	33.3	Directed Network - V2	Yes	Yes	No
16	6	83.3	Baseline - V2	-	-	Yes
	6	50	Directed Network - V2	Yes	Yes	No
17	6	50	Baseline - V2	-	-	Yes
	6	66.7	Directed Network - V2	Yes	Yes	No
18	6	33.3	Baseline - V2	-	-	Yes
	6	66.7	Directed Network - V2	Yes	Yes	No
19	6	83.3	Baseline - V2	-	-	Yes
	6	66.7	Directed Network - V2	Yes	Yes	No
20	6	66.7	Baseline - V2	-	-	Yes
	6	66.7	Directed Network - V2	Yes	Yes	No
21	24	45.8	Undirected Network	Yes	Yes	Yes
22	18	44.5	Undirected Network	Yes	Yes	Yes
23	24	58.3	Undirected Network	Yes	Yes	Yes
24	24	37.5	Undirected Network	Yes	Yes	Yes
TOTAL	375	51.2				

Table A3: Quantile Regressions of the Sequential Gender-Homogeneous Model

	RE†	Q(0.1)	Q(0.3)	Q(0.5)	Q(0.7)	Q(0.9)
Peer performance	0.209***	0.100	0.163	0.266**	0.186	0.227*
	(0.049)	(0.153)	(0.130)	(0.122)	(0.122)	(0.128)
Presence × Peer performance	-0.091	0.001	-0.001	-0.098	-0.019	-0.032
	(0.089)	(0.197)	(0.193)	(0.188)	(0.188)	(0.190)
Peer characteristics						
Wage (log)	-0.03	-0.004	-0.015	-0.082	-0.188	-0.123
	(0.149)	(0.239)	(0.233)	(0.226)	(0.219)	(0.239)
Wealth	0.057	-0.063	0.120	0.011	-0.502	-0.130
	(0.464)	(0.518)	(0.518)	(0.506)	(0.511)	(0.522)
Age	-1.259***	-1.393**	-1.315*	-1.349**	-1.254*	-1.194*
	(0.486)	(0.696)	(0.686)	(0.682)	(0.693)	(0.698)
Fixed Income	-0.29	-0.507	-0.471	-0.244	0.133	-0.225
	(0.822)	(0.881)	(0.899)	(0.904)	(0.920)	(0.929)
ECL engineering school	3.346	3.572	3.530	3.542	3.439	3.53
	(2.47)	(3.075)	(3.079)	(3.081)	(3.081)	(3.079)
Proportion of males	0.719	0.333	0.454	0.421	0.498	0.488
	(1.965)	(2.512)	(2.517)	(2.517)	(2.519)	(2.518)
Individual characteristics						
Wage (log)	0.642***	0.529*	0.463*	0.443**	0.336*	0.484**
	(0.225)	(0.284)	(0.236)	(0.212)	(0.179)	(0.195)
Wealth	0.718	0.211	0.724	0.673	0.521	1.009
	(0.516)	(0.677)	(0.669)	(0.670)	(0.663)	(0.659)
Age	0.061	0.094	-0.001	0.104	0.126	0.175
	(0.139)	(0.227)	(0.219)	(0.230)	(0.224)	(0.232)
Fixed Income	-0.613	-0.788	-0.541	-0.695	-0.357	-0.592
	(0.421)	(0.522)	(0.498)	(0.491)	(0.506)	(0.5)
ECL engineering school	5.756**	5.665**	5.785**	5.771**	5.7776**	5.773**
	(2.354)	(2.572)	(2.568)	(2.567)	(2.564)	(2.564)
Period	0.248***	0.350***	0.285***	0.253***	0.224***	0.172***
	(0.036)	(0.069)	(0.051)	(0.042)	(0.038)	(0.047)
Intercept	31.919**	34.203*	34.221*	34.215*	34.207*	34.228*
	(14.337)	(19.488)	(19.488)	(19.488)	(19.489)	(19.489)
Session Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
N	1392	1392	1392	1392	1392	1392
Non-linearity test in Peers' performance effect‡			$H_0: Q(0.1) = Q(0.3) = Q(0.5) = Q(0.7) = Q(0.9)$			
			p-value = 0.369			

†Random Effects with panel clustered S.E., ‡ Wald test of peers' performance coefficients equality between quantile regressions.
***Indicates 1% significance level, **Indicates 5% significance level, *Indicates 10% significance level.

B. Instructions for the Baseline treatment

(These instructions are for both variants, except the sentence in italics that is used only for variant 2.) We thank you for participating in this experiment on economic decision-making. The session consists of 16 periods during which you will be able to perform a task, as described in detail below.

One of these periods will be randomly selected at the end of the session to determine your earnings in Euros. Your earnings in Euros depend on your performance during this period. Moreover, you will receive an initial endowment for the whole session. The amount of this endowment will be randomly selected among the following values: 2, 4 or 6 Euros. You will be informed on the amount of this endowment for the session before starting the first period.

Your earnings will be paid to you in cash and in private in a separate room.

At the beginning of the session, you will be asked a few personal questions (gender, age, relative wealth of your family compared to the other students, school, year of study).

All your decisions during the session will remain anonymous. You will never have to enter your name in the computer.

Description of each period

Each period lasts 2 minutes 30. During these 2 minutes 30, you are invited to perform the following task.

This task consists of multiplying two-digit numbers by one-digit numbers that are displayed on your screen (for example, 15×3, 22×7). You must enter a value in the corresponding box and submit your answer by clicking the "validate" button. You must make these calculations in your head. It is strictly forbidden to use a pen, a calculator, a mobile phone or any device to multiply the numbers, otherwise you will be immediately excluded from the session and the payoffs. Once you have submitted an answer:

- If this answer is not correct, a message will inform you and you will be able to enter a new answer. Only a correct answer will make another multiplication appear.
- If this answer is correct, your score is increased by one unit and a new multiplication is displayed on your screen.

You can make as many multiplications as you like during each period. You are also allowed to read the magazines that are available on your desk.

Please note that before the beginning of the first period, a practice round of 2 minutes 30 will allow you to train at the task. Your performance during this round will count for the determination of your earnings.

Determination of your earnings

Your earnings during this experiment depend on your piece rate and your score (your number of correct answers) in a period randomly drawn by the computer program at the end of the session. Your piece rate for each correct answer is randomly selected at the beginning of each period. It can change across periods.

This piece rate for each correct answer can take the following values: €0.10, €0.50, €1. Your earnings for the experiment are therefore calculated as follows:

Your total earnings = your initial endowment + (your piece rate × your score in the randomly selected period). The incorrect answers are not accounted for in the determination of your earnings.

Information

At the beginning of the first period, you are informed on the piece rate for the period. Note that the piece rate of the other participants in this session in a given period can differ from your piece rate. But all the participants in the session have to solve the same multiplications and in the same order as you in each period.

You are permanently informed on your current score in the period and on the time remaining until the end of the period. At the end of each period, your final score in the period is displayed, as well as a reminder of your piece rate for the period.

Only in Variant 2: At the end of each period, your score is communicated to one or two other participants. They cannot identify you in the room.

You can find below a copy of the screenshot during the task. The numbers indicated are only an example.

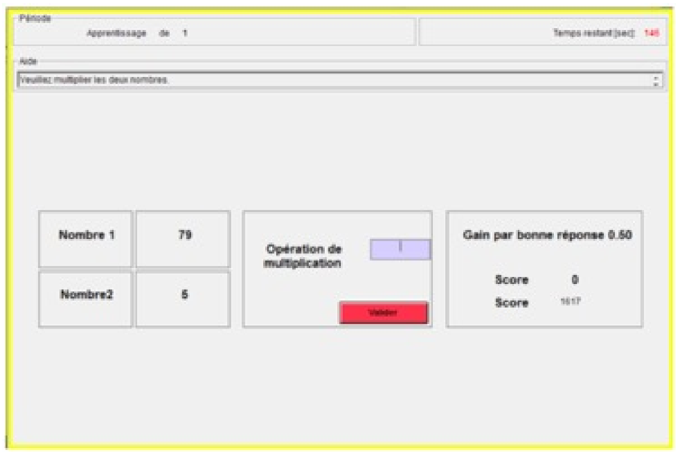

Figure 4: An example of a screenshot - Baseline treatment

To sum up:

- In each of the 16 periods you can solve multiplication problems.
- From one period to the next, the multiplications and the piece rates are modified randomly.
- The other participants receive the same multiplication problems and in the same order as you.
- In each period the piece rates are randomly determined for each participant.
- At the end of each period, you are informed on your score for this period, and on your potential payoff for this period.

Please read again these instructions. If you have any question, please raise your hand and we will answer your questions in private. Once we have answered your questions, a questionnaire will be displayed on your computer screen. Then the practice period will start. The following periods will start automatically. At the end of the session, you will be invited to fill out a final questionnaire.

You are not allowed to communicate with any other participant.

C. Instructions for the Directed Network treatment

(These instructions are for both variants, except the sentence in italics that is used only for variant 1 or 2) We thank you for participating in this experiment on economic decision-making. The session consists of 16 periods during which you will be able to perform a task, as described in detail below.

One of these periods will be randomly selected at the end of the session to determine your earnings in Euros. Your earnings in Euros depend on your performance during this period. Moreover, you will receive an initial endowment for the whole session. The amount of this endowment will be randomly selected among the following values: 2, 4 or 6 Euros. You will be informed on the amount of this endowment for the session before starting the first period.

Your earnings will be paid to you in cash and in private in a separate room. During the session, you will be matched with one or two participants, named "peers" in the rest of these instructions. You will keep the same peers throughout the experiment. You will never know their identity.

(Only in variant 1: This or these peers are not present in the room today: these persons recently participated in another session. During this session, your peer(s) performed the same task as you and their earnings were calculated according to the same rules as you. The difference with you is that they had no peers.)

(Only in variant 2: This or these peers are present in the room today. Your peer(s) perform the same task as you and their earnings are calculated according to the same rules as you. The difference with you is that they receive strictly no information about you.)

At the beginning of the session, you will be asked a few personal questions (gender, age, relative wealth of your family compared to the other students, school, year of study). Then, you will be informed on your peer's answers to these questions. If you have two peers, you will be informed of their mean answers to the questions about their age and the relative wealth of their family. "Men" indicates that your two peers are men; "women" indicates that your two peers are women; "mixed" indicates that one peer is a man and the other peer is a woman.

You will also be informed on the initial endowment of your peer or the average initial endowments of your two peers for the session. All your decisions during the session will remain anonymous. You will never have to enter your name in the computer.

Description of each period

Each period lasts 2 minutes 30. During these 2 minutes 30, you are invited to perform the following task.

This task consists of multiplying two-digit numbers by one-digit numbers that are displayed on your screen (for example, 15×3, 22×7). You must enter a value in the corresponding box and submit your answer by clicking the "validate" button. You must make these calculations in your head. It is strictly forbidden to use a pen, a calculator, a mobile phone or any device to multiply the numbers, otherwise you will be immediately excluded from the session and the payoffs. Once you have submitted an answer:

- If this answer is not correct, a message will inform you and you will be able to enter a new answer. Only a correct answer will make another multiplication appear.
- If this answer is correct, your score is increased by one unit and a new multiplication is displayed on your screen.

You can make as many multiplications as you like during each period. You are also allowed to read the magazines that are available on your desk.

Please note that before the beginning of the first period, a practice round of 2 minutes 30 will allow you to train at the task. Your performance during this round will count for the determination of your earnings.

Determination of your earnings

Your earnings during this experiment depend on your piece rate and your score (your number of correct answers) in a period randomly drawn by the computer program at the end of the session. Your piece rate for each correct answer is randomly selected at the beginning of each period. It can change across periods.

This piece rate for each correct answer can take the following values: €0.10, €0.50, €1. Your earnings for the experiment are therefore calculated as follows:
Your total earnings = your initial endowment + (your piece rate × your score in the randomly selected period). The incorrect answers are not accounted for in the determination of your earnings.

Information

At the beginning of the first period, you are informed on the piece rate for the period. You are also informed of the piece rate of your peer in the same period. If you have two peers, you are informed on their average piece rate. Indeed, your peers can receive different piece rates than yours during a period. Their piece rate is also randomly selected among the following values: €0.10, €0.50, €1. Note that the piece rate of the other participants in this session in a given period can also differ from your piece rate.

(Only in variant 2: Your peer(s) will start the task about three minutes before you: there is always a lag of one period with you. Thus, you will start the first period as soon as your peers will have completed the task in the first period.)

At the beginning of each period, you are also informed on your peer's final score for his piece rate in the period; if you have two peers, you are informed on their mean final score in the same period. Please note that your peer or your peers had to solve exactly the same multiplications as you and in the same order as you in each period. Similarly, all the participants in the session have to solve the same multiplications and in the same order as you in each period.

You are permanently informed on your current score in the period and on the time remaining until the end of the period. At the end of each period, your final score in the period is displayed, as well as a reminder of your piece rate for the period, your peer's piece rate and final score or your two peers' average piece rate and average final score.

You can find below a copy of the screenshot during the task. The numbers indicated are only an example.

To sum up:

- In each of the 16 periods, you can solve multiplication problems.
- From one period to the next, you keep the same peer or the same two peers. (Only in variant 2: This or these peers are present in the room today. Your peers receive no information about you and they start the first period about 3 minutes before you).

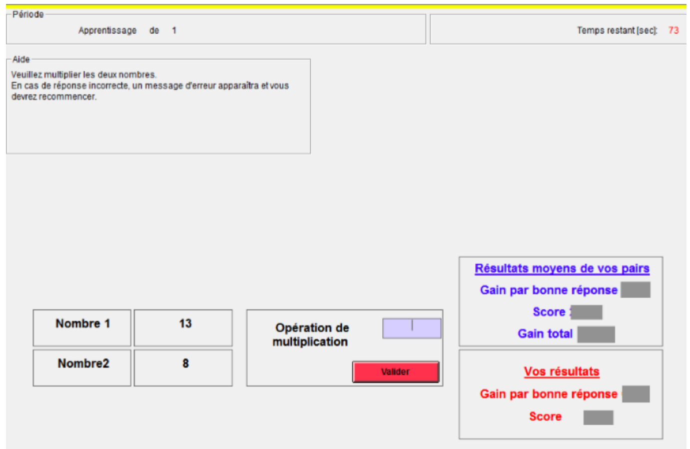

Figure 5: Example of a screenshot - Directed Network treatment

- From one period to the next, the multiplications and the piece rates are modified randomly. Your peer or your peers have received the same multiplication problems and in the same order as you.
- The other participants receive the same multiplication problems and in the same order as you.
- You are informed at the beginning of the period on your peer?s piece rate and on his final score for the same period or on the average piece rate and average final score of your two peers if you have two peers.
- At the end of each period, you are informed on your score and on your potential payoff for this period, and you are reminded your peer?s piece rate and his final score for the same period or the average piece rate and average final score of your two peers for the same period if you have two peers.

Please read again these instructions and answer the questions on the questionnaire that has been distributed to you. If you have any question, please raise your hand and we will answer your questions in private. Once we have answered your questions, a questionnaire will be displayed on your computer screen. Then the practice period will start. The following periods will start automatically. At the end of the session, you will be invited to fill out a final questionnaire.

You are not allowed to communicate with any other participant.

D. Instructions for the Undirected Network treatment

We thank you for participating in this experiment on economic decision-making. The session consists of 4 periods, each divided into several rounds during which you will be able to perform a task, as described in detail below.

One of these rounds will be randomly selected at the end of the session to determine your earnings in Euros. Your earnings in Euros depend on your performance during this round. Moreover, you will receive an initial endowment for the whole session. The amount of this endowment will be randomly selected among the following values: 2, 4 or 6 Euros. You will be informed on the amount of this endowment for the session before starting the first period.

Your earnings will be paid to you in cash and in private in a separate room. During the session, you will be matched with one or two participants, named "peers" in the rest of these instructions. You will keep the same peers throughout the experiment. You will never know their identity.

At the beginning of the session, you will be asked a few personal questions (gender, age, relative wealth of your family compared to the other students, school, year of study). Then, you will be informed on your peer's answers to these questions. If you have two peers, you will be informed of their mean answers to the questions about their age and the relative wealth of their family. "Men" indicates that your two peers are men; "women" indicates that your two peers are women; "mixed" indicates that one peer is a man and the other peer is a woman.

You will also be informed on the initial endowment of your peer or the average initial endowments of your two peers for the session. All your decisions during the session will remain anonymous. You will never have to enter your name in the computer.

Description of each period

Each of the four periods consists of several rounds. The number of rounds can change across periods. Each round lasts 2 minutes 30. During these 2 minutes 30, you are invited to perform the following task.

This task consists of multiplying two-digit numbers by one-digit numbers that are displayed on your screen (for example, 15×3, 22×7). You must enter a value in the corresponding box and submit your answer by clicking the "validate" button. You must make these calculations in your head. It is strictly forbidden to use a pen, a calculator, a mobile phone or any device to multiply the numbers, otherwise you will be immediately excluded from the session and the payoffs. Once you have submitted an answer:

- If this answer is not correct, a message will inform you and you will be able to enter a new answer. Only a correct answer will make another multiplication appear.
- If this answer is correct, your score is increased by one unit and a new multiplication is displayed on your screen.

You can make as many multiplications as you like during each round. You are also allowed to read the magazines that are available on your desk.

Please note that before the beginning of the first period, a practice round of 2 minutes 30 will allow you to train at the task. Your performance during this round will count for the determination of your earnings.

Determination of your earnings

Your earnings during this experiment depend on your piece rate and your score (your number of correct answers) in a round of a period randomly drawn by the computer program at the end of the session. Your piece rate for each correct answer is randomly selected at the beginning of each period. It can change across periods. In contrast, it remains constant across the rounds of a same period.

This piece rate for each correct answer can take the following values: €0.10, €0.50, €1. Your earnings for the experiment are therefore calculated as follows:
Your total earnings = your initial endowment + (your piece rate × your score in the randomly selected round). The incorrect answers are not accounted for in the determination of your earnings.

Information

At the beginning of the first round of each period, you are informed on the piece rate for the period. You are also informed of the piece rate of your peer in the same period. If you have two peers, you are informed on their average piece rate. Indeed, your peers can receive different piece rates than yours during a period. Their piece rate is also randomly selected among the following values: €0.10, €0.50, €1. Note that the piece rate of the other participants in this session in a given period can also differ from your piece rate.

At the end of each round, you are also informed on your peer's final score in the round for his piece rate in the period; if you have two peers, you are informed on the mean final score in this round. Please note that your peer or your peers had to solve exactly the same multiplications as you and in the same order as you during each round. Similarly, all the participants in the session have to solve the same multiplications and in the same order as you in each round.

You are permanently informed on your current score in the round and on the time remaining until the end of the round. At the end of each round, your final score in the round is displayed, as well as a reminder of your piece rate for the period, your peer's piece rate and final score or your two peers' average piece rate and average final score.

You can find below a copy of the screenshot during the task. The numbers indicated are only an example.

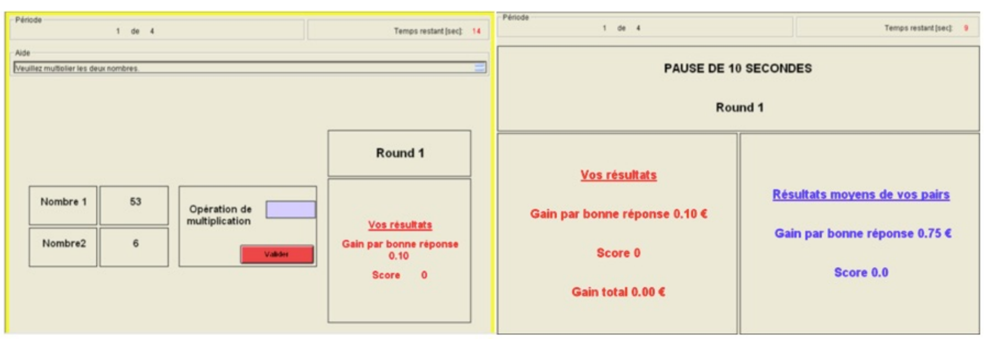

Figure 6: Example of a screenshot - Undirected Network treatment

To sum up:

- Each of the four periods consists of several rounds during which you can solve multiplication problems.

- From one period to the next, you keep the same peer or the same two peers. The piece rates are randomly determined.
- During a period, you keep the same piece rate across rounds.
- From one round to the next, the multiplications are modified randomly. Your peer or your peers receive the same multiplication problems and in the same order as you.
- You are informed at the beginning of the period on your peer's piece rate or on the average piece rate of your two peers.
- At the end of each round, you are informed on your final score and your potential earnings for this round, and on your peer's score or on the average score of your two peers. You are reminded your piece rate and your peer's piece rate or the average piece rate of your two peers.

Please read again these instructions and answer the questions on the questionnaire that has been distributed to you. If you have any question, please raise your hand and we will answer your questions in private. Once we have answered your questions, a questionnaire will be displayed on your computer screen. Then the practice period will start. The following periods will start automatically. At the end of the session, you will be invited to fill out a final questionnaire.

You are not allowed to communicate with any other participant.