Status lies in the eye of the beholder: Evidence from eye-tracking data

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Abstract

Using eye-tracking methodology, the current study investigates how people look at faces in the context of a social hierarchy. The first goal of the study was to characterize how participants distribute their attentional resources to a set of faces displayed on a vertical hierarchical scale including three social ranks (high, middle and low). In the first phase of the experiment, participants had to learn a hierarchy based on performance in competitive games. The participants' rank, the other players' rank, and the spatial orientation of the scale (highest social rank at the top of the vertical scale vs. highest social rank at the bottom) were manipulated. The results revealed that participants looked more at other players who occupy the *highest* than the *lowest* social rank but did not look more at another player who was ranked *higher* than *lower* than themselves when that player was in the middle position. Hence, participants were more sensitive to the highest vs. lowest rank contrast than to the higher vs. lower rank contrast. The results also revealed an influence of spatial orientation of the scale: less visual attention was allocated to the highest-ranking players when they appeared at the bottom than at the top of the spatial scale. The second goal of the study was to investigate how participants explored the face of each player. This was addressed in the second phase of the experiment, in which participants were presented with each player's face individually. The results did not show any effect of players' rank but revealed that in some circumstances, participants in the higher-ranking position were less likely to allocate visual resources to other players.

Introduction

Navigating the social world requires a sharp understanding of interpersonal relationships and their outcomes. A recurring factor that structures the social life of humans and other species is inequality in relations. In dyadic interactions, an individual is often in an advantageous position with respect to another: S/he may exert power, monopolize food access and enjoy

greater social support or prestige. Within a group, the set of asymmetrical relations constitutes a *hierarchy*. Social hierarchies have a strong impact on the lives of individuals. In stable hierarchies, high-status individuals benefit from more resources, are in better health and are more likely to reproduce.

Due to the correlation between status and reproductive success, ethologists and evolutionary psychologists argue that social hierarchies exert selection pressure on the mind and suggest that cognitive mechanisms are well attuned to the stratification of the social environment [1–4]. Even at a more proximal level, recognizing who is dominant and subordinate, predicting how an individual will behave according to his status, and knowing who is entitled to which resources as a function of status can be crucial. Consider, for instance, the deleterious consequences of mistaking a dominant individual for a subordinate individual might have in some species. A wide range of studies have reported that sophisticated cognitive abilities are dedicated to hierarchies in humans and other species. For example, male fish *A. Burtoni* can infer ascendancy relations in fights through transitive inference, that is, when observing a set of dyadic fights such as $A > B$; $B > C$; $C > D$; $D > E$, they anticipate $B > E$ (where “ $>$ ” means “wins over”; [5]). In humans, preschoolers and even infants can make subtle social inferences on the basis hierarchical relationships [6], and at 10 months, infants seem to use body size to predict dominance relationships [7].

From an adaptive perspective, social asymmetries should result in cognitive asymmetries, that is, more cognitive resources should be allocated to high-status individuals. This stems from the greater social influence they exert. On the one hand, affiliating with and imitating high-status individuals can be beneficial to maintain or enhance one’s own social rank; on the other hand, avoiding conflicts with such individuals is obviously preferable. Hence, to optimally exploit the stratified structure of the social environment, it should be better to attend to, to remember and to track what high-status individuals do or communicate.

A burgeoning literature provides convincing evidence that concurs with this view. First, a memory advantage for high-status targets has been shown. For instance, Ratcliff et al. [8] observed that male faces associated with high-status occupational titles (e.g., doctor) were better remembered than male faces associated with low-status occupational titles (e.g., fry cook), and this difference persisted when status was associated with more arbitrary labels (e.g., two different colors symbolizing high vs. low status). Moreover, in paradigms presenting sets of photographs of people for short periods of time, participants were better at remembering the spatial location of individuals dressed in high-status attire (e.g., four star generals) than individuals dressed in low-status attire [8], and they estimated higher frequencies of high-status male faces [9].

Second, high-status individuals exert a greater influence on the allocation of cognitive resources of their observers, as revealed by the influence of status on the gaze cueing effect. This effect shows that human and non-human primates target their attention in the direction their conspecifics look at [10–13]. It turns out that this effect tends to be greater for dominant than for subordinate faces [14] and is greater for male faces associated with a high-status CV than for male faces associated with a low-status CV [15,16].

Third, eye-tracking studies report asymmetry in social attention. Participants target their eye fixations more to pictures of men dressed in business professional attire than to men dressed in casual attire [9,17], and when watching videos of groups completing decision-making tasks, they spend more time looking at individuals who were classified as high status in the discussion [18].

How is gaze allocated to a vertical hierarchical scale?

Using eye-tracking methodology, the current study extends previous work in three ways. First, a striking feature of the abovementioned literature is that participants are not involved in

the hierarchy they are observing and are not related to the individuals embedded in that hierarchy. Participants are usually passive bystanders, and their own status is not at stake. However, a great deal of our social experiences involve situations in which we directly take part, and our knowledge of others' status mostly concerns people with whom we are connected. In the current study, the participant had a well-defined rank and could easily compare his own position with those of the other members of the hierarchy. As shown by Figure 1 (Fig 1), he could have a high, a middle or a low rank and could see himself and other individuals exhibiting the same or different ranks. We thus investigated the distribution of the participant's attentional resources to his face and to the faces of other individuals in different ranking conditions.

===== **Figure 1 about here** =====

Second, to include the participant in a social context in which his status and the others' status would be readily identifiable, we introduced another kind of hierarchy. While in previous eye-tracking studies, hierarchy was conveyed through physical cues [19] or power and influence in collective discussions [20], in the current study, the hierarchical context relied upon a competitive game situation involving a comparative evaluation of cognitive skills. Such a procedure, which was inspired by our previous EEG study on face perception ([20], see also [21–23]), allows us to go beyond the dichotomous contrast between high and low absolute status. By introducing three ranks, we could distinguish targets that occupy the highest or lowest ranks from targets that occupy a higher or lower rank than the participant rank. In particular, a middle ranking player neither occupies the highest nor the lowest rank, but has a higher rank than a participant who is in the lowest-ranking position and has lower rank than a participant who is in the highest-ranking position. This will allow us to examine whether participants are more sensitive to differences between extreme positions in the hierarchy (highest vs. lowest

rank contrast) or to differences between positions relative to their own rank (higher vs. lower contrast), or both.

Third, we also manipulated the physical space in which the hierarchy was conveyed. The eye-tracking methodology obviously enables investigating the scanning of a given space and how spatial factors guide visual attention. The representation of social asymmetries often relies on space. Hierarchies are typically represented on a vertical array wherein the rank order of higher- to lower-status individuals is organized from the top to the bottom of the vertical space. Organization charts in companies, rankings in sports competitions, or the representation of power through pyramids use verticality as a metaphor of hierarchy: “high status is up; low status is down” [25]. A wide range of experimental results suggest that such a metaphor is deeply rooted in cognitive mechanisms of both human and non-human primates [26–31]. For instance, participants are faster at identifying a word referring to high power (i.e., boss) when it is presented at the top than at the bottom of a computer screen and are inversely faster at identifying a word referring to low power when it is presented at the bottom than at the top of the screen [26]. In addition, words expressing high and low power respectively induce a shift of attention to the upper and lower visual field [30].

In contrast with earlier studies in which social targets were presented on a horizontal axis and in which the spatial position was irrelevant to status, in the current study participants were presented with a vertical ranking that was either congruent (high status up and low status down) or incongruent (high status down and low status up) with the spatial metaphor of hierarchy. We therefore investigated whether a low-level physical factor, namely, the position on a vertical axis, modulates the social attention allocated to high- and low-status individuals. On the one hand, if participants’ attention is governed by abstract conceptions of hierarchy that only relies on past social competitive situations, the fixation patterns of high- and low-status individuals should be similar in both congruent and incongruent hierarchies. On the other hand,

if hierarchy representations are partially grounded in a spatial framework, then the upper and bottom parts of the vertical space should both convey implicit social information, that is, highness and lowness of social status, respectively. A high-status individual presented at the bottom of the vertical space would therefore be associated with two contradictory pieces of information: explicit high status with respect to his performance but implicit low-status with respect to his spatial location. If an attentional advantage to high-status individuals is observed in the congruent condition, it could therefore be reduced or even disappear in the incongruent condition. Hence, the manipulation of the vertical space should allow investigating how social and low-level physical factors contribute to the visual scanning of a hierarchy. Moreover, at a methodological level, this manipulation avoids a confound between status and spatial location.

How are faces gazed upon in a hierarchy context?

A second purpose of the study is to describe how participants look at faces according to their status. Once participants terminated the exploration of the vertical hierarchy they were embedded in (first phase of the experiment), they were then presented with each of the individuals' faces separately and were requested to recognize their status (second phase of the experiment; see Fig 2). Research on face processing has shown that most of ocular fixations are targeted at the internal features of the face, namely, the eyes, the nose and the mouth [32–34], and more so the eyes than any other region [35–37]. Moreover, social categories, such as race and familiarity, are known to modulate this pattern. The perception of own-race faces results in more fixations on the eye region and more active scanning than other-race faces, which reflects a facilitation in the encoding of in-group members' faces [38–40]. Moreover, participants fixate more on the eyes of familiar than unfamiliar faces [41,42], and as a face becomes (more) familiar, it is explored with fewer and more symmetrical fixations, which are focused on more-

restricted facial features [36,41,42]. Some authors have proposed that such an observational pattern reveals a more efficient visual encoding of familiar faces [42].

With respect to hierarchy, the greater gaze cueing effect elicited by high-status targets as compared to low-status targets [14–16] suggests that, everything else being equal, participants may look more at the eyes of high-status faces. Moreover, recent EEG studies have reported that ERP components associated with face processing can be modulated by the face's social status [21–24]. In a study using a similar design as the present experiment [21], but in which only the face presentation phase was analyzed, we found that the highest-ranking faces elicited a larger amplitude of the late positive potential than the lowest-status faces and were associated with a larger reduction in oscillatory alpha power [20, 39, see 40 for a review]). This pattern is in line with the view that more attentional resources are allocated to high-status faces. Given that the eyes are the part of the face that draw attention more, it could be that the eyes of the highest-status faces attract attention even more.

In a study showing that individuals who are considered leaders in discussions are looked at more often than others [18], the authors also examine which parts of the individuals were mostly inspected and specifically analyzed the eyes, the rest of the head and the rest of the body. In the three status conditions, the authors indicate that the eyes were more frequently fixated on than the rest of the face and the rest of the body, but they did not report that the proportion of fixations on the eyes as compared to the rest of the face was significantly modulated by status. Similarly, in a recent study in which status was established through CV-based questionnaires, the authors did not report a significant tendency to look more at the eyes of high-status faces [43]. However, they did find that the way participants looked at high- and low-status individuals' faces depended on whether they believed those individuals would later look back at them while looking at them [43]. In particular, they looked less at the eyes of high-status individuals when they thought they would look back at them than when they did not think so.

Taken together, these studies indicate that high-status faces are not necessarily looked at differently from low-status faces, but the latter study suggests that the situational context in which status information is embedded might impact how faces will be gazed upon. An element of context that may influence the gaze on faces is the observer's own status. In a recent study, Cui et al. reported that when participants were primed with high social power, they showed a reduced gaze cuing effect than when they were primed with low social power [19]; however, this pattern was only observed for female and not for male participants. In the second phase of the experiment, we not only explore whether the gaze allocation to high- versus low-status faces differs but also how the social status of the participant modulates this allocation.

Material

Ethics Statement

All participants gave written informed consent for the study, which was approved by the local Ethical Committee (Comité de Protection des Personnes, Gerling agency - Ref: CAL n°2011-030, n°IRB 11263). All patients consented to participate in the research on their own behalf. Prior to the task, the experimenter ensured that the patients had the capacity to consent by asking a series of questions about their understanding of the study.

Participants

Twenty-eight right-handed healthy male participants were recruited (mean = 22.40 years $\pm$ 2.66 SD, median = 21.96 years) and participated in this study. All volunteers were French (comparable in age) and had similar academic backgrounds and levels. They all had normal or correct-to normal vision; 23 of them showed right eye dominance and 5 left eye dominance. We tested only male volunteers and presented them only with male faces, as it is known that both genders differ in their sensitivity to competitive settings [44]. All participants consented to participate in the research on their own behalf and were compensated for their participation.

Stimuli

The social target stimuli set used in the hierarchy learning phase and in the rank evaluation phase involved 72 high-resolution photographs of males' faces taken from the NimStim Set of Facial Expressions standardized database [45] and from the stimuli set used by Baudouin and Gallay [19]. All faces were neutral and presented a direct gaze orientation. No remarkable details, such as glasses, earrings, piercings or mustaches appeared on the faces. The pictures were transformed into grayscale images, normalized in size and luminance, aligned on the eyes' position and were displayed on a screen with a white background. Only the participant's photograph was displayed in color. During the hierarchy learning phase (phase 1 - see below), faces were combined to form 3-level rankings. Each ranking contained the participant's face photograph and the four players' faces (Fig 1). During this phase, faces were reduced to occupy a visual angle of $4.9^\circ \times 3.9^\circ$ (205 x 159 pixels) separated by a minimal space of 4.9 x 3.9 pixels. During the rank categorization phase (phase 3 – see below, Fig 2B), faces were presented one by one in the center of the screen and were subtended at a vertical angle of 22.2° and a horizontal angle of 17.5° at a viewing distance of 70 cm (921 x 717 pixels).

Design and procedure

We followed the same general procedure as described in a previous EEG study [21]. Before starting the experiment, the participant's face was photographed and inserted into the group of faces as a landmark of his position. A competitive context was created to ensure that the participant believed he was included in a hierarchy. At the beginning of the experiment, he was informed that other volunteers had already completed the same games he would play, and that their scores and pictures had been stored in a database. The experimenter explained to the participant that his performance would be compared to three “former players”, represented by their photographs, and randomly chosen from the players' database. The participant was told

that these “former players” had been previously ranked according to their scores as the best, middle or worst competitor. Participants were thus presented with three vertically organized faces corresponding to the **highest, middle** and **lowest rank**. Additionally, an unknown rank face was displayed at the bottom left corner of the screen and served as filler. The participant was provided with information regarding his own performance, which was either categorized in the highest, middle or lowest rank. Four different faces were used in each block so that a given face never occurred in two different blocks. The participant could have the **highest, middle** or **lowest rank**. The participant’s rank was manipulated across blocks: 6 blocks for the highest rank, 6 for the middle rank and 6 for the lowest rank (Fig 1A). The block order was set randomly across participants. Moreover, each face was contextualized only once in the experiment, and the presentation of faces was counterbalanced across participants so that each face was associated with each possible rank with the same probability.

After receiving the instructions, the participant was seated in front of a screen at a viewing distance of 70 cm. He first performed a training session constructed as an experimental block. Faces and games presented during the training were not used in the experimental blocks. The experiment was created using Presentation®14.3 (Neurobehavioral System, <http://www.neurobs.com/>) and was divided into eighteen blocks, including eighteen different tasks. Each experimental block was designed as follows: a hierarchy learning phase that served to contextualize faces within a hierarchy (1), a ranking restitution phase (2), and a rank categorization phase (3). Analyses of interest were performed on ocular data collected during Phase 1 and on behavioral and ocular data obtained during Phase 3.

Phase 1: hierarchy learning

In a task, four simple perceptive tests were given to the participant, such as detecting as quickly as possible which side of the screen contained a greater amount of dots (Fig 2A). The participant was told that his performance in each of the four tasks, allegedly based on reaction

time and validity, would be compared to that of three other players who completed the same tasks. This comparison gave rise to an intermediate ranking presented after each task and during which eye recordings were performed. Other players' faces were displayed vertically on three hierarchical levels and were labeled as the "best", the "middle" and the "worst" player (Fig 1A). The participant's photograph was inserted in the ranking and had the same rank as one of the other players. Fourteen participants were presented with the vertical ranking in the upright orientation (highest and lowest ranks respectively placed at the top and the bottom), and the other 14 participants were presented with the vertical ranking in the inverted orientation (highest and lowest ranks respectively placed at the top and the bottom). Unlike the highest and the lowest ranks, the spatial location of the middle rank remained unchanged in the two types of orientation.

The participant was told that the rankings were established by a cumulative score of the player's performances on all tasks. For example, the participant's rank after the second task was claimed to be determined by the averaged performance over the two first tasks and so on until the final ranking following the fourth task. Real performances were not taken into account to rank the participant. Intermediate rankings were set according to the final intended ranking. Three of the 4 rankings were identical to the intended one, and in one task randomly chosen among the first two, the participant's rank differed by one position in the hierarchy. This procedure was applied to maintain credibility. After the participant gave his answer, he was informed of his accuracy, and the ranking was then presented for 7 seconds (Fig 2A). Over the 18 blocks, 72 rankings were presented, 24 in each of the three participant's ranking conditions.

Phase 2: ranking restitution

At the end of the game, participants were asked to reproduce the cumulative ranking established over the 4 tasks. To do so, they had to use the mouse and move the 5 photographs (those of the four players and their own photograph), which were *horizontally* displayed at the

bottom of the screen. If the ranking was incorrect, a fifth task (never shown before) was presented before starting the third phase. This fifth task occurred only 6 times.

Phase 3: rank evaluation of each individual face

This phase consisted in presenting one of players' faces shown in Phase 1 for 4 s. Each face was preceded by a fixation cross for 2 s and was then followed by a red point during a randomly chosen interval between 600 and 900 ms to announce a question. The question concerned the player's rank compared to the participant's rank: "superior?" (i.e., "was his rank superior to yours?"), "equal?", "inferior?", "no rank?" (Fig 2B). The participant had to answer as quickly and accurately as possible by pressing one of the three response keys: "yes", "no" or "can't tell". The four faces presented in the earlier phases were presented 4 times so that participants had to deal with 16 trials for each block. Trials were displayed in a pseudo-randomized order, with no identical face appearing in two consecutive trials. Over the course of the experiment, 288 trials (72 faces presented 4 times) were presented to the participants, comprising 216 target trials and 72 control trials (faces associated with no specific rank). The target trials included 24 trials for each player rank (highest, middle, lowest) x participant rank (highest, middle, lowest) sub-conditions; that is, 72 either by player rank condition or by participant rank condition. As in Phase 1, participants were free to look at the pictures in any way they wanted, but they were asked to look at the fixation cross presented before the face. Once the third phase was completed, a break was proposed and the participant was instructed to start the next block with four different players' faces. Participants were explicitly asked to limit their body movements during blocks, and their viewing distance was tracked online to ensure they maintained a consistent distance among them.

===== **Insert Figure 2 about here** =====

Eye recordings

Two-dimensional ocular positions were recorded by the Tobii X120 Eye-tracker (SR Research Ltd.), with a sampling rate of 60 Hz (one measure every 17 msec). The eye-tracker was disposed directly beneath the presentation screen and tilted 20 degrees upwards, as recommended in the Tobii Studio manual. Experimental recordings were preceded by a five-point fixation calibration procedure implemented in the Tobii Studio software. No filters were applied on data online.

Data analysis and statistics

During the hierarchy learning phase, we quantified the visual attention allocated to each of the four players' faces and the participant himself by defining Areas Of Interest (AOIs) for each photograph (AOI Highest-rank player – AOI Middle-rank player – AOI Lowest-rank player – AOI Participant – AOI No Rank - 205 x 159 pixels) and around the associated labels (four in total) (Fig 1B). During the rank categorization phase, we defined AOIs corresponding to the **eye region** (AOI Eye: 110 x 400 pixels), the **nose and mouth** region (AOI Nose: 240 x 250 pixels) and **the rest of the face** (AOI Rest of the face: 921 x 717 pixels subtracted from the AOIs Eye and Nose), as depicted in Figure 1C. For all faces, the three AOIs had the same size, but their locations were adjusted depending on the characteristics of the faces in such a way that the AOI Eye was centered on the middle point between the two eyes and the center of the AOI Nose was aligned with the center of the AOI Eye.

We collected the number of fixations (i.e., the occurrence with which a target is looked at) and the observation time (i.e., the duration with which a target captures visual attention). Fixations in a particular AOI were extracted from the raw signal using an algorithm implemented in Tobii Studio 2.X software and designed following the Velocity-Threshold Identification fixation model (I-VT) proposed by Salvucci et al. [46]. This algorithm is based on the analysis of sliding windows (size fixed at 166 ms, i.e., 10 frames at 60 Hz) into which

two adjacent data points were considered to belong to the same fixation if the velocity between them remained under a certain threshold (fixed at $0.21 \text{ pixels.ms}^{-1}$ i.e., $35/(16.6 \times 10)$). The **Mean Number of Fixations** (MNF) was then computed, and the **Mean Observation Time** (MOT) in a particular AOI was calculated by summing the elapsed time between each frame spent in this AOI. Following Van der Werf et al. [47], when the time difference between each frame exceeded $334 \pm 67 \text{ ms}$, it was considered a blink, and the corresponding frames were not taken into account. Moreover, trials were rejected from the analysis when ocular data were lost for more than 10 % of the total stimulus presentation time.

Finally, we analyzed behavioral responses in the rank categorization phase to determine whether accuracy (Hit percent) and speed (Reaction Time) to categorize faces were influenced by hierarchical position. The statistical analyses included repeated measures analyses of variance (ANOVA) (within-subjects and between-subjects factors are stated below) and Least Significant Difference (LSD) Fischer tests for post hoc comparisons.

Results

Exploration of the hierarchy during the learning phase

Visual exploration of players' faces embedded in rankings

We first examined the MNF on the different players' faces inserted in the rankings in an ANOVA including the player's rank (3 levels: **highest, middle or lowest**) and the participant's rank (the same 3 levels) as within-subject factors and the ranking orientation (**upright, inverted**) as a between-subject factor. The analysis revealed a main effect of the player's rank ($F(2,52) = 82,64$; $p < .001$; partial $\eta^2 = 0.76$, see Table 1), indicating first, that participants fixated more on the middle player's face than the two others (middle vs. highest and lowest player's faces: all $ps < .001$), and second, that the highest player's face received more fixation than the lowest player's face ($p = .002$). There was also a significant interaction

between the participants' and the players' ranks ($F(4,104) = 46,03$; $p < .001$; partial $\eta^2 = 0.64$, see fig 3A). The LSD post hoc analysis indicated that i) when participants were in the middle position, they made more fixations on the highest-ranking player ($3,27 \pm 0,83$ SD) than on the lowest-ranking player ($2,86 \pm 0,49$ SD; $p = .002$), ii) they fixated more on the farthest ranking face when they were in the lowest position (i.e., looking at the highest-ranking player; $2,98 \pm 0,76$ SD) than when they were in the highest position (i.e., looking at the lowest-ranking player; $2,56 \pm 0,39$ SD) ($p = .002$), and iii) they fixated more on their equal player when they were in the highest than in the lowest position (respectively $2,69 \pm 0,57$ SD vs. $2,42 \pm 0,48$ SD; $p = .038$). However, they did not make significantly more fixations on the middle-ranking player who was higher than themselves (i.e., participants in the lowest rank looking at the middle-ranked player; $4,54 \pm 0,81$ SD) than on the middle-ranking player who was lower than themselves (participants in the highest rank looking at the middle-ranked player; $4,46 \pm 0,75$ SD) ($p = .57$) (Fig 3A).

Table 1. Mean ($\pm$ SD) number of fixations and observation time (in milliseconds) on players' faces according to their rank (highest, middle or lowest).

Players' rank	MNF		MOT (ms)	
	M	SD	M	SD
Highest player	2,98	0,63	1468,4	276,0
Middle player	4,02	0,55	1924,3	259,1
Lowest player	2,61	0,37	1322,3	244,0

There was no main effect of ranking orientation ($F(1,26) = 0,72$; $p = .40$; partial $\eta^2 = 0.027$), but we found an interaction between this factor and the players' rank ($F(2,52) = 7,14$; $p = .002$; partial $\eta^2 = 0.22$, see fig 3B). In the upright orientation, the highest-ranking players elicited a greater MNF than the lowest-ranking players ($p < .001$), but this difference was no longer observed in the inverted orientation ($p = .73$). Moreover, the highest-ranking players

were more fixated in the upright than in the inverted condition (highest-ranking players at the top vs. at the bottom of vertical scale) ($p = .003$), while for the lowest-ranking faces, there was no significant difference between these two conditions ($p = .15$). Additionally, faces displayed at the top of the rankings were more fixated when they were associated with the highest (in the upright condition) than the lowest rank (in the inverted condition) ($p = .008$), while there was no effect of the hierarchical rank for faces displayed at the rankings' bottom ($p = .25$) (Fig 3B).

===== **Figure 3 about here** =====

Finally, there was a main effect of the participant's position on the MNF of players' faces ($F(2,52) = 11,39$; $p < .001$, partial $\eta^2 = 0.30$), indicating that participants ranked in the middle position fixated less on all the players' faces than participants ranked in the highest ($p = .002$) or in the lowest ($p < .001$) position. We also observed an interaction between this variable and the ranking's orientation ($F(2,52) = 5,24$; $p = .008$, partial $\eta^2 = 0.17$). In the upright orientation, lowest-ranked participants tended to fixated more the others players faces compared to highest-ranked ($p = .056$) and middle-ranked participants ($p = .048$), while in the inverted orientation, participants fixated more the others faces when they were ranked both at the lowest and at the highest position, compared to the middle one (all $ps < .001$). The triple interaction between players' rank, participants' rank and ranking orientation was not significant ($F(4,104) = 1,46$; $p = .23$, partial $\eta^2 = 0.05$).

Second, we analyzed the MOT of players' faces with an ANOVA including the player's rank (3 levels: **highest, middle or lowest**), the participant's rank (the same 3 levels) as within-subject factors and the ranking orientation (**upright, inverted**) as a between-subject factor. A main effect of player's rank ($F(2,52) = 59,89$; $p < .001$; partial $\eta^2 = 0.69$, see Table 1) was observed, indicating that participants looked longer at the middle player's face than at the two

others (middle vs. highest and lowest player's faces: all p s < .001) and that they explored longer the highest player's face than the lowest player's face ($p = .014$). We found a significant interaction between players' and participants' rank ($F(4,104) = 49,31$; $p < .001$; partial $\eta^2 = 0.65$, see fig 4A). The post hoc analysis indicated that middle-ranked participants looked longer at the highest player ($1647,6\text{ms} \pm 345,9 \text{ SD}$) than at the lowest player ($1416,9\text{ms} \pm 279,3 \text{ SD}$; $p < .001$). Furthermore, participants ranked in the lowest position spent more time viewing the highest ranked player ($1443,5\text{ms} \pm 358,5 \text{ SD}$) than participants ranked in the highest position did on the lowest-ranking one ($1300,0\text{ms} \pm 237,2 \text{ SD}$; $p = .028$). However, there was no significant difference between the observation time of their equal in the highest ($1314,1\text{ms} \pm 257 \text{ SD}$) and in the lowest position ($1249,9\text{ms} \pm 316,9 \text{ SD}$; $p = .32$). Finally, participants did not spend significantly more time looking at the middle-ranked player who was higher than themselves (participants in the lowest position: $2197,6\text{ms} \pm 381,4 \text{ SD}$) compared to looking at the middle-ranking player who was lower than themselves (participants in the highest position: $2142,3\text{ms} \pm 376,6 \text{ SD}$) ($p = .39$) (Fig 4A).

There was no main effect of rank orientation on the MOT of players' faces ($F(1,26) = 0,52$; $p = .48$, partial $\eta^2 = 0.019$), but we observed a significant interaction between this variable and the player's rank ($F(2,52) = 11,22$; $p < .001$, partial $\eta^2 = 0.30$, see fig 4B). As for the MNF, the longer MOT for the highest- compared to the lowest-ranked players' faces was found for the upright orientation ($p < .001$) but not for the inverted one ($p = .12$). Moreover, participants looked longer at the highest ranked players when they were presented at the top (upright) than at the bottom (inverted) of the rankings ($p < .001$), and they spent more time looking at the lowest-ranked players in the inverted condition (when they were at the top of the ranking) than in the upright condition ($p = .012$). Additionally, faces presented at the top of the rankings were observed longer when they were associated with the highest compared to the lowest rank (p

=.043), while there was no influence of rank on faces presented at the bottom of rankings ($p = .24$) (Fig 4B).

===== **Figure 4 about here** =====

Finally, the effect of the participant's rank was significant ($F(2,52) = 13,1$; $p < .001$; partial $\eta^2 = 0.33$); when they were in the middle ranking, participants spent less time looking at other players' faces than when they were in the highest ($p = .002$) and lowest ($p < .001$) rankings. Neither the interaction between participant's rank and the ranking orientation ($F(2,52) = 2,15$; $p = .13$; partial $\eta^2 = 0.08$), nor the triple interaction ($F(4,104) = 1,91$; $p = .11$; partial $\eta^2 = 0.07$) were significant.

Visual exploration of participants' face embedded in rankings

Additionally, we conducted ANOVAs to evaluate the effect of displaying concomitantly the participant's face with faces of other players on the allocation of visual attention. We thus analyzed the MNF and MOT of the participant's face and of the corresponding equal player (displayed at the same position) using the participant's position (3 levels: **highest, middle or lowest**) and the type of face (2 levels: **the participant's face or the player's face**) as within-subject factors. For both MNF and MOT, we reported a main effect of the face's type (MNF: $F(1,27) = 144,29$; $p < .001$, partial $\eta^2 = 0.84$; MOT: $F(1,27) = 199,9$; $p < .001$, partial $\eta^2 = 0.88$), indicating that participants made more fixations and observed longer the player's face ranked at the same position than their own faces. Finally, none of the analyses revealed a significant interaction between the type of face and the participant's position (MNF: $F(2,54) = 1,90$; $p = .16$, partial $\eta^2 = 0.07$; MOT: $F(2,54) = 0,82$; $p = .45$, partial $\eta^2 = 0.03$).

The exploration pattern of faces in the ranking evaluation phase

To characterize the observation pattern of faces in a hierarchical context (second phase of the experiment), analyses were conducted on the **MNF** and **MOT** on different faces. First, a repeated measures ANOVA on the MNF including the player's rank (3 levels: **highest, middle and lowest**), the participant's rank (the same 3 levels) and the AOI (3 levels: **AOI Eye, AOI Nose and AOI Rest of the face**) as within-subject factors and the ranking orientation (2 levels) as a between-subject factor was conducted. The analysis revealed a main effect of AOI ($F(2,52) = 44,45; p < .001$), indicating that the AOI Eye received significantly more fixations ($5,21 \pm 1,97$) than the AOI Nose ($2,47 \pm 1,51$), while the AOI Rest of the face was the least fixated on ($1,06 \pm 0,64$; all $ps < .001$). The analysis also showed a main effect of the participant's rank ($F(2,2) = 4,59; p = .01$), indicating that participants ranked in the middle position made more fixations on faces than participants in the highest-ranking ($p = .004$) or lowest-ranking ($p = .09$) positions as a trend. There was no significant effect of the player's rank ($F(2,52) = 0,12; p = .9$) nor of the ranking orientation ($F(1,26) = 0,12; p = .9$). Moreover, a three-way interaction revealed that the MNF made on the eye area depended on the participant's rank and the ranking orientation ($F(4,104) = 2,54; p = .04$, see Fig 5). In the upright orientation, participants made fewer fixations on the eyes of the other players when they were in the highest-ranking position ($5,22 \pm 2,33$) than when they were in the middle- ($5,65 \pm 2,39; p = .01$) or lowest-ranking position ($5,55 \pm 2,19; p = .03$, see Table 2, Fig 5 – left panel). In contrast, when the ranking was inverted, no difference was observed in MNF on the eye region according to participants' position (Fig 5 – right panel).

===== **Figure 5 about here** =====

Table 2. Mean ($\pm SE$) number of fixations made on the three AOIs Eye, Nose and Picture according to the participant's rank (highest, middle or lowest) in the upright ranking orientation.

Number of Fixations	AOI Eye		AOI Nose		AOI Picture	
	M	SE	M	SE	M	SE
Highest participant	5,22	2,33	2,29	1,63	1,05	0,77
Middle participant	5,65	2,39	2,25	1,62	1,09	0,71
Lowest participant	5,55	2,19	2,35	1,36	0,90	0,46

Second, an ANOVA including the same within- and between-subject factors was performed on the MOT. There was a main effect of AOI ($F(2,52) = 50,88$; $p < .001$), showing that participants looked longer at the eyes ($2407,2 \pm 714,5$ ms) than at the nose ($1152,8 \pm 727,2$ ms), and then at the rest of the face ($410,3 \pm 230,2$ ms) (all $ps < .001$). There were no main effects of player's rank ($F(2,52) = 2,01$; $p = .1$), of participant's rank ($F(2,52) = 0,99$; $p = .4$), or of ranking orientation ($F(1,26) = 0,005$; $p = .9$) on the MOT of the three AOIs, and no interaction was reported either between player's rank and the AOI ($F(4,104) = 0,49$; $p = .7$) or between the participant's rank and the AOI ($F(4,104) = 1,27$; $p = .3$).

Face rank evaluation phase: behavioral results

Participants were quite accurate in categorizing players' ranks and obtained 84,8 % of correct responses (mean number of misses $\pm$ SD = $32,9 \pm 5,6$ among 216 trials, minimum number of misses = 22, maximum number = 42). The repeated measures ANOVA including players' rank (3 levels: highest, middle, lowest) and participant's rank (the same 3 levels) as within-subject factors and ranking's orientation (2 levels: upright, inverted) as a between-subject factor revealed a main effect of the players' rank on Hit percent ($F(2,52) = 8,62$; $p < .001$, partial $\eta^2 = 0.25$; see Table 3, Fig 6A), indicating that participants were more accurate in categorizing the rank of the highest-ranking player compared to the middle-ranking ($p < .001$) and the lowest-ranking ($p = .001$) players (Fig 6A). The analysis also showed a main effect of

the participant's rank ($F(2,52) = 6,01$; $p = .004$, partial $\eta^2 = 0.19$; Fig 6B). The LSD post hoc tests showed that participants were more accurate in categorizing a face's rank when they were in the middle than in the highest ($p = .002$) or lowest ($p = .01$) position (Fig 6B).

===== **Figure 6 about here** =====

Table 3. Mean ($\pm SE$) Hit percent and Reaction time associated with the rank evaluation task on players' faces.

Player's rank	Hit (%)		RT (ms)	
	M	SE	M	SE
Highest	88,4	4,4	1271,0	315,5
Middle	82,7	6,3	1297,2	315,2
Lowest	83,2	5,1	1309,5	323,7

Discussion

The first goal of the current study was to describe how participants allocate their visual attention to individuals in the context of a social hierarchy. In contrast with early work, the current experiment a) included the participant in the hierarchy, b) introduced a competitive situation involving three ranks and c) manipulated the spatial orientation of the rankings. The second goal of the study was more specific, namely, to examine how participants gaze at the faces of individuals exhibiting different ranks.

The analysis of gaze allocation during the hierarchy observation phase showed that there were more eye fixations and longer fixation times for the lowest-ranking participants looking at the highest-ranking individuals than *vice versa* (i.e., highest-ranking participants looking at the lowest-ranking individuals). This result is in line with primate studies investigating social attention in another type of asymmetrical context, namely, dominance hierarchies; those studies report that subordinate individuals target their gaze more at higher-ranking individuals than *vice*

versa [48–50]. Similarly, in the middle ranking position, participants made more fixations and looked longer at highest- than lowest-ranking individuals.

This general pattern could either be accounted for by a tendency for participants to focus more attention on individuals who have a *higher* rank than themselves or by a tendency to focus on individuals who exhibit the *highest* rank. The three ranking positions actually enable these two possibilities to be disentangled, since *higher*-ranking targets were not necessarily the *highest* ones, and *lower*-ranking targets were not necessarily the *lowest* ones. In particular, middle-ranking targets could have a higher or a lower rank than the participant himself, and it turned out that this contrast did not modulate the level of visual attention they received from participants. In contrast, the highest- and lowest-ranking targets could have the same rank as the participant, and the results indicate that the participants tended to make more fixations on their equal in the highest position than on their equal in the lowest position. It is thus rather the *highest vs. lowest* contrast than the *higher vs. lower* contrast that modulated the participant's visual attention. Participants attended more to highest than lowest-ranking individuals but did not necessarily attend more to individuals who ranked higher than individuals who ranked lower than themselves.

An intriguing question is why participants did not systematically allocate more resources to the middle individuals who ranked higher than to the middle individuals who ranked lower than themselves. One possibility is related to the type of hierarchy employed. In the current experiment, the hierarchy takes the form of a contest involving several individuals wherein the highest-ranking individuals can be viewed as winners and the other contestants as non-winners. Being the winner involves the notion of a full achievement regarding a specific task and confers a higher social prestige, while being a non-winner involves the failure to reach the highest rank of the hierarchy. In other words, the highest-ranking individuals qualitatively differ from the other members by their success, while non-winners quantitatively differ from

each other by their level of failure (i.e., more or less unsuccessful in reaching the peak of the hierarchy). Hence, a middle-ranking individual whose rank is higher than the participant does not much differ from a middle-ranking individual whose rank is lower. In both cases, the middle-ranking individual equally missed the key social position and could be similarly categorized and scrutinized.

However, such a pattern may obviously be quite specific to competition-based hierarchies. For instance, in dominance or power hierarchies, a middle-ranking individual exerts a greater impact on their lower-ranking peer as they influence them more, are entitled to more rights and can be more threatening. Looking more at higher- than lower-ranking individuals could become more appropriate in such a context. An interesting avenue of research would thus be to compare how different kinds of hierarchies (e.g., power, prestige, asymmetry in resource) differentially modulate the attentional resources allocated to higher- vs. lower-ranking individuals. Another important factor is the distance between the individuals in the hierarchy, that is, the number of ranks a hierarchy contains. The results obtained in the current experiment might result from the relatively low number of ranks (i.e., 3). In a competition-based hierarchy that involves many ranks (e.g., 100) and many contestants, individuals who did not reach the peak of the hierarchy but who are close to it (e.g., 2nd or 3rd rank) may be considered much more prestigious than those who are far away from it (e.g., 98th or 99th). It could thus be that a large social distance between a higher- and a lower-ranking target may modulate the resources allocated to such targets.

Another factor that might have contributed to the current pattern is the instability of the hierarchy in the first phase of the experiment. The ranking was updated after each perceptive task, and one of the participant's positions differed from his final position [51]. Past studies have found that unstable hierarchies cause greater stress and increase the level vigilance of individuals at the top of the hierarchy [52]. In the current experiment, this might have incited

participants to gaze more at their equal when they were in the highest-ranking position than when they were in the lowest-ranking position.

In highlighting that the highest- vs. lowest-ranking contrast modulated more social attention than the higher vs. lower ranking contrast, we suggested that the highest-ranking individuals are likely to receive more attention than others, but of course, this is based on the assumption that everything else is equal. In fact, when the participants were in the two extreme positions, it was the middle-ranking individual who received more attention (see Figs 3 and 4). However, this can trivially be explained by the central spatial position occupied by this individual: a central position in a given space necessarily attracts more attention than peripheral positions. Although trivial, this explanation shows the importance of spatial factors in scanning a hierarchy.

Spatial orientation is one of the factors we actually manipulated. For half of the participants, the ranking orientation was upright (highest-ranking individuals at the top of the vertical axis), and for the other half, it was inverted (highest-ranking individuals at the bottom of the vertical axis). This manipulation had a large impact and modulated the effects we have described so far. In the upright orientation, a very clear advantage for the highest-ranking individual was observed: wherever the participants were located in the hierarchy, namely, in the lowest, middle or highest positions, and whatever the measure taken into account, namely, MNF or MOT, the results demonstrated that more attentional resources were allocated to the highest- than the lowest-ranking individual. In contrast, this advantage systematically disappeared in the inverted orientation, and it was even found that the MOT for lowest-ranking faces was longer than the MOT for highest-ranking faces. Another way to consider the influence of orientation is to compare how the same social targets were looked at in the two types of ranking. In particular, it appeared that participants allocated more resources to the highest-ranking individuals in the upright than the inverted ranking.

These results can be accounted for by the fact that spatial verticality is a metaphor of hierarchy and that the top of a vertical axis implicitly represents the highest rank of a social hierarchy [26–31]. If more attention is allocated to cues indicating the highest rank, the congruent orientation (highest rank at the top and lowest rank at the bottom of the vertical axis) conveys more such cues than the incongruent one (highest rank at the bottom and lowest rank at the top of the vertical axis). It then becomes understandable that the highest-ranking individuals were more fixated on in the upright than the inverted orientation. Such individuals might be perceived as exhibiting a higher rank in the upright than inverted orientation. Past research has actually shown that the perception of the status of the highest-ranking individuals could be modulated by spatial factors. For instance, in a study by Gniessner and Schubert [27], participants could see organization charts showing either a long (7 cm) or a short (2 cm) distance between two successive hierarchical ranks. The authors reported that when the distance was long, the participants perceived the individual associated with the highest rank as being more powerful than when the distance was short. Similarly, Schubert [26] found that powerful animals (gorilla, lion) were evaluated as more powerful when their pictures appeared at the top than at the bottom of a screen.

We now turn to the discussion of the rank evaluation phase during the player's face presentation. The analysis on MNF and MOT did not show that faces were looked at differently according to their rank. In particular, participants did not specifically look more at the eyes of the highest-ranking faces as compared to other faces. This absence of effect may seem at odds with three findings: i) the greater gaze cueing effect for dominant and high-status faces [14–16], ii) the larger Late Positive Component [20, see also 21, 40] and iii) the higher gaze allocation to the highest-ranking faces in the first phase of the experiment. All these findings indicate that faces associated with the top of a social hierarchy capture cognitive resources more. Moreover, given that the eyes are the central element people look at in a face, it could be expected that the

advantage for the eyes would be more pronounced for those faces. This is not what was found, but in the two earlier studies that investigated how status modulates the scanning pattern of faces, the authors did not report a significantly greater advantage for the eyes of the higher-status faces as compared to other faces [18,43]. The social rank itself may, thus, not be sufficient to deeply modulate the nature of a face's visual exploration.

The lack of status modulation on the observation of players' eyes can also be compared with results obtained in an EEG study using the same paradigm [21]. While the Event-Related Potentials analysis revealed that the rank of the face modulated the LPP, which indexes high-order social evaluation, it did not show any influence on the N170 component, which reflects the structural encoding of faces. Interestingly, previous research has found that the exploration of the eye region impacts N170 characteristics. For instance, when the eyes are presented alone, they elicit a larger N170 than the entire face [53–55], and the rate of early fixations on the eye region is negatively correlated with N170 amplitude [56]. The absence of status modulation on the N170 [21] and on the scanning of players' eyes both suggest that hierarchy, as instantiated in the current paradigm, does not affect the perceptual processing of the face. This does not, however, mean that hierarchy has no effect on a more cognitive aspect of face processing, as revealed by the modulation of LPP [21], nor that a more physical instantiation of hierarchy, through dominance displays, for instance, might influence the visual scanning of faces [57,58].

Even though no effect of player's rank was found, factors related to the participant revealed an interesting pattern. As indicated in the introduction, Gobel et al. [43] manipulated the participants' beliefs regarding what people whom they are looking the face will later do. They observed that participants looked less at the eyes of high-status individuals, when they believed those individuals would later look back at them than when then they did not believe so. In the present experiment, a key factor that was manipulated was the participant's own rank. As in the study of Gobel et al. [43], this participant-related factor also influenced the face

exploration strategy. In the upright condition, participants in highest-ranking position were less likely to make fixations on the eyes of the players' faces than in the middle- and lowest-ranking positions. This effect was also observed at a larger scale, when faces were presented in rankings: highest-ranking individuals made less fixations on their competitors' faces than lowest-ranking participants. This suggests that those participants are less likely to pay attention to the key feature of the others' faces, namely their eyes. This could be accounted for by the tendency of high-status people to pay less attention to what others feel, think, or communicate. For example, during interpersonal interactions, higher-status individuals are less accurate at detecting others' emotions [59] and are less likely to gaze at their partners [19], laugh or nod their heads [60]. Likewise, individuals who are assigned to a high-power role discount advice they received from others to a greater extent than individuals assigned to a low-power role [61]. They are also less likely to take the others' perspective [62], and they demonstrate fewer prosocial behaviors, such as generosity, charity, or helpfulness [63]. Neuroimaging findings have even revealed that when dealing with social information, high- compared to low-status individuals exhibited reduced activity in brain networks associated with the processing of mental states of others [64].

In conclusion, the current study showed that a number of interacting factors can influence the level of visual resources allocated to individuals enrolled in a hierarchy and the way those people are looked at. Player's rank, participant's rank and ranking orientation differentially contributed to the visual exploration strategy elicited by hierarchical rankings. First, while there was no attentional advantage for the player who ranked higher than the participant, there was a clear advantage for the highest-ranking player whatever the participant's position. Second, this advantage was much more pronounced for upright than inverted rankings, which confirmed that spatial orientation communicates hierarchy-related information. Third, while player's rank did not influence the visual exploration of a face's characteristics, the participant's rank did show such an influence in the upright orientation. Of

course, these findings emerge in a specific experimental situation, and future research should explore how the nature of the hierarchy, the stability of the hierarchy, population characteristics such as gender, and culture may modulate the current pattern.

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Author Contributions

Conceived and designed the experiments: AB AC JBVDH JYB. Performed the experiments: AB. Analyzed the data: AB AC JBVDH. Contributed materials/analysis tools: AB AC. Wrote the paper: AB AC JBVDH JYB.

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Figures

Fig 1. Critical stimuli and representation of their associated Areas Of Interest (AOIs).

A) Rankings displayed during the hierarchy learning phase. These three-level rankings were presented to the participant after each round of the game. The participant could be either the best (configuration 1), the middle (configuration 2) or the worst player (configuration 3), and his photograph was displayed in color. In configurations 1 and 3, participants had an equal-ranking player (framed in yellow), a closest different player (framed in blue) and a farthest different player (framed in green). In configuration 2, the participant had an equal-ranking player and a higher- and lower-ranking player (both differing by one rank from the participant's

position, framed in purple). Definition of the AOIs: B) for rankings displayed during phase 1, AOIs were considered on participants' and players' faces (framed in different colors); C) for faces displayed during phase 3, AOIs were defined on the eyes (blue), on the nose-and-mouth region (green) and on the rest of the face (orange).

Fig 2. A) Examples of task and associated ranking proposed to the participant during phase 1. B) Temporal course representation of stimuli displayed during phase 3.

Fig 3. MNF of players' faces displayed in rankings (phase 1).

The bar charts represent MNF differences A) in the three players' rank conditions (highest, middle and lowest) according to the participant's rank and B) in the three players' rank (highest, middle or lowest) according to the two ranking orientations (upright or inverted). * indicates a significant difference ($p < 0.05$), and bars in the plots correspond to the standard errors of means

Fig 4. MOT on players' faces displayed in rankings (phase 1).

The bar charts represent MOT differences A) in the three players' rank conditions (highest, middle and lowest) according to the participant's rank and B) in the three players' rank (highest, middle or lowest) according to the two ranking orientations (upright or inverted). * indicates a significant difference ($p < 0.05$), and bars in the plots correspond to the standard errors of means.

Fig 5. MNF on the different faces' AOIs during the rank categorization phase (3).

The bar chart represents fixations performed on the three faces' AOIs according to participants' rank (highest, middle or lowest) when rankings in phase 1 were upright (left panel) and inverted (right panel). * indicates a significant difference ($p < 0.05$), and bars in the plots represent the standard errors of means.

Fig 6. Mean Hit percentage associated with the rank categorization task (phase 3) according to players' rank (A - highest, middle or lowest) and participants' rank (B - highest, middle or lowest). * indicates a significant difference ($p < .05$), and bars in the plots represent the standard errors of means.