COGNITIVE SCIENCE
A Multidisciplinary Journal

Cognitive Science 44 (2020) e12866

ISSN: 1551-6709 online
DOI: 10.1111/cogs.12866

A Forward Bias in Human Profile-Oriented Portraits

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Received 14 January 2020; received in revised form 8 May 2020; accepted 12 May 2020

Abstract

The spatial composition of human portraits obeys historically changing cultural norms. We show that it is also affected by cognitive factors that cause greater spontaneous attention to what is in front rather in the back of an agent. Scenes with more space in front of a directed object are both more often produced and judged as more aesthetically pleasant. This leads to the prediction that, in profile-oriented human portraits, compositions with more space in front of depicted agents (a "forward bias") should be over-represented. By analyzing a large dataset (total *N* of 1,831 paintings by 582 unique identified European painters from the 15th to the 20th century), we found evidence of this forward bias: Painters tended to put more free space in front of, rather than behind, the sitters. Additionally, we found evidence that this forward bias became stronger when cultural norms of spatial composition favoring centering became less stringent.

Keywords: Visual art; Portraits; Spatial composition; WikiArt; Historical norms; Anteroposterior body structure; Cultural evolution; Cultural attraction

1. Introduction

The capabilities, dispositions, and constraints of human cognition impact the forms taken by culture in all domains, for instance in medical practices (Miton, Claidière, & Mercier, 2015), or the shapes taken by written characters (Changizi, Zhang, Ye, & Shimojo, 2006; Morin, 2018). Art offers a fertile domain to investigate how cultural productions are shaped by cognitive factors (Cavanagh, 2005). Characteristics of the human visual system, for instance, affect color or spatial structure preferences (see Palmer, Schloss, & Sammartino, 2013 for a review). Cultural productions are also embedded in social and historical contexts that modulate the effects of cognitive factors. The present

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study illustrates the role of cognitive factors in shaping the spatial composition of human profile-oriented portraits and the way they interact with cultural factors over historical time.

Some features of human portraits are likely to reflect cognitive processes specifically involved in the perception of agents and more particularly in the perception of faces. Morin (2013) has shown, for instance, how direct gaze of the sitter tends to predominate when pictorial conventions allow it. Morin explains this tendency by a cognitive disposition to treat gaze as a source of social information that is easier to exploit in direct than in averted gaze. Here, we demonstrate the existence in Western portrait painting of another tendency, specific to profile portraits, which we call "forward bias" and which consists in leaving more space in front of the sitters than behind them (thus decentering the sitters). Remarkably, in most of the period considered, there was no explicit cultural norm favoring this forward bias; on the contrary, there was a strong explicit norm in favor of centering the sitter in the frame, a norm from which portraits with a decentered sitter depart.

Spatial composition, and in particular the positioning of depicted objects or agents on the canvas, has long been a topic of interest in understanding aesthetical appreciation in visual arts (Puttfarken, 2000). There exists a strong tendency for centering horizontally any object represented on its own on a rectangular canvas (Arnheim, 1983; Palmer & Guidi, 2011; Tyler, 2007b). Arnheim (1965, 1983), drawing on his background in Gestalt theories of perception, suggested that rectangular frames come with a particular structural skeleton supporting spatial composition. This idea of structural skeleton (sometimes called net) was supported by a fit-rating experiment (Palmer & Guidi, 2011), and partially supported by an analysis of pictures with high aesthetic ratings (Jahanian, Vishwanathan, & Allebach, 2015). On the other hand, McManus, Stöver, and Kim (2011) did not find support for its existence. Horizontally centering an object in the frame increases both explicit judgments of balance (Leyssen, Linsen, Sammartino, & Palmer, 2012; McManus, Edmondson, & Rodger, 1985) and aesthetic preference (Leyssen et al., 2012; Mitsui & Noguchi, 2002; Palmer & Guidi, 2011; Sammartino & Palmer, 2012). Spatial compositions in which the focal object is centered are also easily and spontaneously *produced* (Locher, Cornelis, Wagemans, & Stappers, 2001; Locher, Jan Stappers, & Overbeeke, 1998; Puffer, 1903).

What is true of paintings of single objects in general is true in the special case of paintings of portraits of a single sitter. Aleem, Correa-Herran, and Grzywacz, (2017), for instance, found a tendency for sitters to be centered in a set of Renaissance portraits. There is even evidence that painters tend to place one of the sitter's eyes so that it crosses the vertical center line (Tyler, 1998, 2007a). However, this observation about production is not matched by a similar effect in aesthetical preferences: In a two-alternative forced-choice paradigm (2AFC), portraits with one eye perfectly centered were not preferred by naïve viewers over portraits which did not center one of their sitter's eye (McManus & Thomas, 2007). These results suggest that centering one of the sitter's eyes might be more present in *producing* portraits than it is in *appreciating* it.

When a single object depicted is vertically symmetrical, there is no clear reason why there should be more space on one side of it rather than on the other side. Centering such an object on a rectangular canvas makes for an overall symmetrical composition. This is the case in particular with front-view portraits. On the other hand, when an object depicted is vertically asymmetrical and moreover has a back–front orientation, as do human faces seen in profile, then putting more space in front of it or behind it is not indifferent. There may be good reasons not only for preferring (in production or in appreciation) one of these two possible placements but also for preferring it to equal space on both sides, and hence for preferring a decentered composition. In the production and appreciation of profile portraits, there are, we suggest, two conflicting tendencies, one in favor of centering, the other—the forward bias—in favor of leaving more space in front of the sitter and therefore of decentering.

Not every object has a back and a front. Arguably, it is a genuine intrinsic property of some animals and some artifacts, and beyond that, it is property projected by analogy. Identifying a front and a back or, more abstractly, directionality in the shape of agents, and in particular other humans, is highly relevant to interacting with them. Directionality of agents and directionality of their movements are related and perceptual and cognitive systems throughout the animal kingdom rely on this relationship (Apfelbach & Wester, 1977; Catania, 2009; Cooper, 1981; Hernik, Fearon, & Csibra, 2014; Smith, 1973). Most animals' body plan is bilaterally symmetrical with an anteroposterior axis, and thus their movement potential tends to be along this main axis and toward the front, rather than toward the back. Cues of this anteroposterior axis are the basis for perceptual decision-making in humans. For instance, movement direction can be used to disambiguate the front from the back of an ambiguous figure (Bernstein & Cooper, 1997; Pavlova, Krägeloh-Mann, Birbaumer, & Sokolov, 2002), animal body's directionality can be used to disambiguate an ambiguous movement direction (McBeath, Morikawa, & Kaiser, 1992), and orientation of a moving elongated symmetrical object biases perception and prediction of its motion trajectory (Morikawa, 1999). In the case of a stationary novel agent, its body directionality may support expectations of its future action-direction from early on in human infancy (Hernik et al., 2014). There should therefore be, we suggest, in humans and other animals, a strong prior expectation that the direction of an agent's movements will be congruent with their body directionality.

Another clear source of directional information easily accessible to the observer is agent's gaze. Observed shifts of gaze-direction bias covert visual attention (gaze-cueing) in very young human infants and possibly newborns (Farroni, Massaccesi, Pividori & Johnson, 2004). They elicit overt shift of observer's own gaze (gaze-following) in infants as young as 5–6 months of age, raised in diverse cultural contexts (Gredebäck, Astor, & Fawcett, 2018; Gredebäck, Astor, & Fawcett, 2008; Hernik & Broesch, 2019; Senju & Csibra, 2008). Gaze-cueing and gaze-following may be best expressed in response to dynamic and communicative gaze-signals in infants (Farroni, Johnson, Brockbank, & Simion, 2000; Gredebäck et al., 2018; Hernik & Broesch, 2019; Senju & Csibra, 2008), although such signals are not required for adults (Friesen & Kingstone, 1998). Gaze-following is also widespread across non-human animals (Itakura, 2004; Kano et al., 2018).

In humans and many other animals, body directionality and direction of gaze may sometimes diverge. However, when observing agents looking in front of them, the strong tendency of a gaze-cue to engage observer's attention in the direction indicated by the cue combined with the expectation of forward movement should cause the observer to pay much more attention to what is in front of the agents than to what is behind them. This gives initial plausibility to the hypothesis that, in visual arts, the area in front of a forward-looking agent will be considered more relevant than the area behind them. There should therefore be a tendency to put more space in front of agents than behind them. This forward bias may well extend to artifacts. When artifacts such as vehicles or teapots are seen as having a front and a back, this is inferred from the direction of the movements through which they perform their function (or the direction of the movement they induce in a user in the case of, say, an arrow sign).

There is some experimental and observational evidence for these conjectures. Experimental participants tend to put more space in front, rather than behind agents and oriented artifacts in a drag-and-drop task (Palmer & Langlois, 2017). Pictures in which agents, humans and animals, or artifacts are depicted with more free space in front than behind them have also been judged aesthetically more pleasing (Palmer, Gardner, & Wickens, 2008). Evidence of this tendency has also been observed in actual cultural productions: in depiction of animals in three European sources (two animal painters, Stubbs and Bewick, and a medieval bestiary, in Bertamini, Bennett, & Bode, 2011), and in contemporary movies from four different movie directors (Bode, Bertamini, & Helmy, 2016). These studies, however, did not consider historical dynamics, and they reflect the production of only a few individuals.

In the present study, we test for the existence of a forward bias in human profile-oriented portraits, on a large dataset. When they are not exactly centered (i.e., the free space is not equally divided between space in front of and behind the sitter), we predict that there should be more space in front of the sitter than behind them (Hypothesis 1).

Given that a centering norm and a forward bias favor two, strictly speaking, incompatible types of spatial composition (centering agents represented in profile versus leaving more space in front of agents and hence decentering them), we expect that the relative frequency of portraits exhibiting the forward bias mostly depends on external factors, such as historical norms and favored formats. Centering has for centuries been an explicit composition norm in Western portraits' tradition. From the Renaissance onward, however, spatial composition norms have been progressively relaxed (Puttfarken, 2000). While the norm of centering in particular became less imperative, to the best of our knowledge, no new explicit cultural norm emerged favoring leaving more space in front rather than behind a sitter depicted in profile. As an anonymous reviewer rightly noted, we cannot exclude that some tacit norm favoring a forward bias might have emerged. We will argue, however, that the evidence we collected casts doubt on this interesting suggestion.

We also test, therefore, whether, as an effect of the relaxation of composition norms, the forward bias has become more frequent and more marked over historical time (Hypothesis 2). This implies two predictions: (a) The more recent the portraits, the more

frequently they should show the bias and (b) the stronger should the bias be (i.e., the larger the difference between the free space in front and behind the agent).

We tested these two hypotheses (existence of a forward bias and historical tendency to allow greater expression of this forward bias) on one large-scale dataset (N = 1,831 portraits, from 582 unique painters), curated from two main sources ArtUK.org and WikiArt.org.

2. Methods

2.1. Data collection and sources

We defined profile portraits as portraits having only one eye visible. Additionally, to be included in our analyses, a portrait had to fulfill the following criteria: (a) it had to depict only one sitter, (b) its sitter had to neither be interacting with any particular object nor involved in performing any particular activity, and (c) the sitter's orientation had to be unambiguous. Pipes, cigarettes, and masks, because they are usually placed in front of the agent and thus might influence the sitter's placement, also constituted a reason for exclusion.

We also excluded artworks for which spatial composition could not be assessed, such as cropped details of artworks (rather than full frame), and portraits with frames that were not rectangular (e.g., oval frames). Artifacts other than rectangular paintings or drawings (e.g., plates, mixed materials including 3D parts, stamps, and canvases or supports with irregular shapes) were also excluded. Finally, all pictures that included mirrors or reflections of the sitter were also excluded, as they included two pictures of the sitter.

The ArtUK website was consulted between August and early October 2018. As stated in the pre-registration, we first used the keyword *profile* to search the website. Search results were then filtered by a naive research assistant to keep only the portraits fulfilling our inclusion criteria (N = 221). The WikiArt website was consulted between early October 2018 and early February 2019. A research assistant, who was unaware of our research hypotheses, went through each painter's page within the portraits subsection and selected paintings that fulfilled our inclusion criteria (N = 1,610 portraits). There was no overlap between both datasets—given that both datasets had very similar results, they are presented here collapsed into a single dataset (see Data S1 and report on OSF for results on each dataset separately).

Our full dataset included a total of 1,831 portraits, including 1,095 female portraits, 729 male portraits, and seven sitters of ambiguous gender. In all, 1,086 of the portraits were oriented to the left, and 745 to the right. Works of 582 unique painters were represented, each contributing between 1 and 70 portraits (M = 3.09, Med = 1, SD = 5.58). Only 27 (4.6%) painters contributed 10 or more paintings to our sample. The earliest paintings were from 1,425, and most recent ones from 2018, with most of the portraits dated late 19th and early 20th century (see Fig. 1).

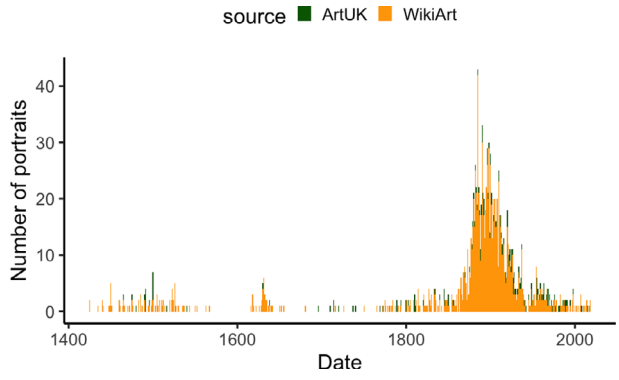

Fig. 1. Composition of our dataset, including the number of portraits by source (WikiArt in orange, ArtUK in dark green). It represents the 1,429 portraits (out of 1,831) for which we were able to obtain a precise date.

2.2. Measures

Akin to Bertamini et al. (2011), relevant measures were defined as horizontal distances between the sitter and the margins of the frame, taken from the farthest extremity at one end (most often, chin or nose) to the farthest extremity at the other end (back of the head, hair) of the body of the sitter itself, as shown in Fig. 2 (see Data S1 for details about

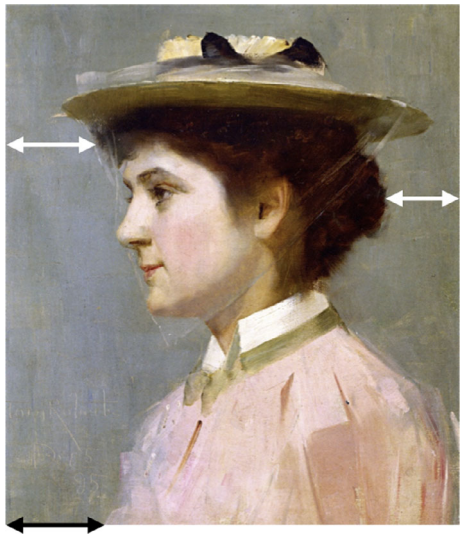

Fig. 2. *Miss Isobel McDonald* (1895) by Tom Roberts (public domain). Here, 54.54% of the free space is placed in front of the sitter for the head measures (white arrows), and all (100%) of the free space measured at the level of the body is placed in front of her (black arrow, the sitter's garment touches the limit of the frame behind her, meaning that this measure equals zero). Measures excluded hats but included hair as part of the sitter's head.

frames). Hats and other paraphernalia were not taken into account, as they are not part of the agent per se. Whenever portraits depicted sitters' bodies below the shoulders, another set of measure was taken, again from the farthest extremity at one end to the farthest extremity at the other end, but at the level of the body, rather than at the level of the face. We present results for both sets of measures.

The proportion of free space in front of the sitter, referred to as strength of the bias, is defined as $p = \frac{\text{pixels in front}}{\text{pixels in front} + \text{pixels behind}}$, that is, as the proportion of the free space placed in front of the agent relative to all the free space available—see Fig. 2. For a portrait to be considered as showing the bias, it had to have its proportion of free space in front of the sitter strictly larger than the proportion of free space behind the sitter.

All measures were taken by a research assistant who was naïve to the present study's hypotheses. Slightly over 30% of each dataset's portraits were recoded by a second coder (author H.M.). Intercoder reliability was high, as confirmed by two-way mixed intraclass correlations assessing absolute agreement (icc function, irr package), ICC = 0.965 (95% CI [0.962, 0.968]), on 2,416 measures taken over 604 portraits.

2.3. Pre-registration and data accessibility

The research design and data analyses were decided before data collection and pre-registered on June 28, 2018 on Open Science Framework. The initial registration,[1] full research records (including Data S1), and raw data can be found here: https://osf.io/6dsnx/?view_only=098a4d5bccee48f69e6e37ebe9a14508.

3. Results

3.1. Hypothesis 1: Prevalence of a forward bias

When using head measures, 1,395 out of 1,831 of the paintings showed the forward bias, which is significantly different from the 50% chance level as tested by a Fischer exact test (OR = 11.73, 95% CI [9.31, 14.84], $p < .001$). On average, 62.32% of the free space was located in front of the sitter's head, which was higher than expected by a one-sample Wilcoxon test ($V = 1{,}378{,}700$, $p < .001$, $r = 0.575$). Similarly, when using body measures, 926 out of 1,619 of the paintings showed the bias, which is significant as tested by a Fischer exact test against the chance level of 50% (OR = 3.58, 95% CI [2.85,4.51], $p < .001$). On average, 60.55% of the free space was located in front of the sitter's body, which was higher than the 50% expected by chance, by a Wilcoxon test ($V = 669{,}140$, $p < .001$, $r = .262$).

This forward bias was present in both left- and right-facing portraits. For head measures, the bias was significantly more marked in right-facing portraits (Med = 61.25) than in left-facing portraits (Med = 59.31), as confirmed by a Mann–Whitney U test, $U = 434{,}150$, $Z = 2.81$, $p = .004$. For body measures, left-facing portraits (Med = 64.06) had not significantly more of their free space localized in front of their sitters than right-

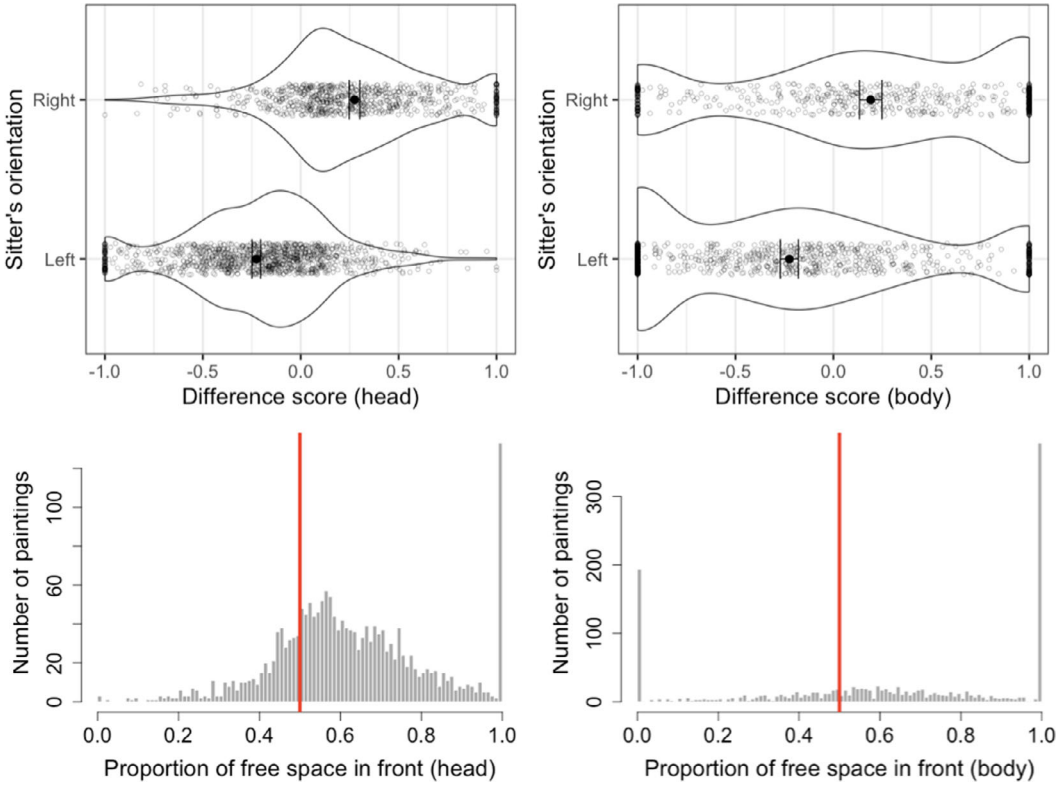

Fig. 3. Prevalence of the forward bias in profile-oriented portraits. Above: The values on the *x*-axis show difference scores calculated as (right free space − left free space)/(right free space + left free space). They range from − 1, meaning that all the free space was located on the sitter's left, to 1 meaning that all the free space was located on the sitter's right (0 means equal amounts of free space on both sides of the sitter). The *y*-axis represents the sitter's orientation (left- or right-facing). The plain round dot represents the mean, the error bar the 95% CI, the outer shape the distribution (density), and the gray small circles are individual data points. Below: Number of paintings by their ratio of the free space in front of the sitter to free space behind the sitter. On the *x*-axis, 0 means that all the free space is situated behind the sitter, 0.5 that there is as much space in front and behind, and 1 that all the free space is in front of the sitter. Head measures are represented on the left (and were available for all the 1831 portraits in our dataset), and body measures on the right (available for 1,619 portraits).

facing portraits (Med = 62.70), as indicated by a Mann–Whitney U test, U = 247,340, Z = 0.776, p = .438.

Both datasets showed that painters exhibited a tendency to put more free space in front, rather than behind the sitter, and this whether measures were taken from the body or from the head of the sitter. The forward bias was slightly more marked for right-facing than for left-facing portraits (see Fig. 3).

3.2. Hypothesis 2: Historical emergence of the forward bias

Out of 1,831 portraits, 1,429 had a precise date. Dated and non-dated paintings did not significantly differ in how their proportion of space in front versus behind the sitter they were, neither for head measures (Mann–Whitney U test, $U = 281{,}490$, $Z = -0.474$, $p = .635$) nor for body measures ($U = 171{,}100$, $Z = 0.08$, $p = 0.929$).

The distribution of dates in our datasets was strongly negatively (left-) skewed, and it did not follow a normal distribution (Shapiro–Wilk: $W = 0.65$, $p < .001$, skewness = −2.34). To approximate normal distribution, for regression analyses, the date variable was mirrored, log-transformed, and mirrored back.

3.2.1. Hypothesis 2a: Increase over time in the prevalence of the portraits conforming to the forward bias

We ran a binary logistic regression with portrait's date as the independent variable with showing (coded as 1) or not showing (coded as 0) the forward bias and date as a predictor to determine whether date impacted how likely a portrait was to exhibit the bias. This model did show that more recent paintings were more likely to show a forward bias when measured from the sitter's head (OR = 3.15, 95% CI [1.96, 5.12], $p < .001$—Wald $\chi^2(2) = 369.4$, $p < .001$ for the whole logistic regression), but not when measured from her body (OR = 1.27, 95% CI [0.85, 1.93], $p = 0.248$—Wald $\chi^2(2) = 26.7$, $p < .001$ for the regression overall).

3.2.2. Hypothesis 2b: Increase in the amplitude of the forward bias

Overall decentering, that is, the asymmetry between the spaces on both sides of the sitter (either in the direction of a forward bias or opposite to it), increased over time in both our datasets. There was a positive correlation between date and overall ex-centricity: The more recent the portrait, the less centered its sitter, on both our datasets and types of measures ($r_\tau = .13$, $p < .001$, 95% CI [0.095, 0.161] for head; $r_\tau = .08$, $p < .001$, 95% CI [0.046, 0.118] for body measures). This was also confirmed by a simple linear regression with log-transformed date as an independent variable and how decentered were the sitters as a dependent variable ($F(1, 1{,}427) = 51.16$, $p < .001$, $R^2 = .03$): More recent portraits had a more decentered sitter ($b = 0.09$, 95% CI [0.07, 0.12], $t(1{,}427) = 7.15$, $p < .001$), when using measures from head. Similar results were obtained for a simple linear regression on body measures ($F(1, 1{,}264) = 22.44$, $p < .001$, $R^2 = 02$): More recent portraits decentered their sitters more ($b = 0.06$, 95% CI [0.03, 0.08], $t(1{,}264) = 4.74$, $p < .001$).

The more recent a portrait was, the more pronounced was the forward bias (see Fig. 4). When considering only portraits exhibiting a forward bias (i.e., having more free space in front than behind a sitter), the more recent the portrait, the stronger the forward bias ($r_\tau = .14$, $p < .001$, 95% CI [0.104, 0.184] for head measures; $r_\tau = .10$, $p < .001$, 95% CI [0.046, 0.144] for body measures).

A linear regression ($F(1, 1{,}097) = 20.03$, $p < .001$, $R^2 = 0.02$), with log-transformed date as an independent variable and strength of the bias (measured as the ratio of space in front of the sitter to the space behind the sitter) as the dependent variable, suggested

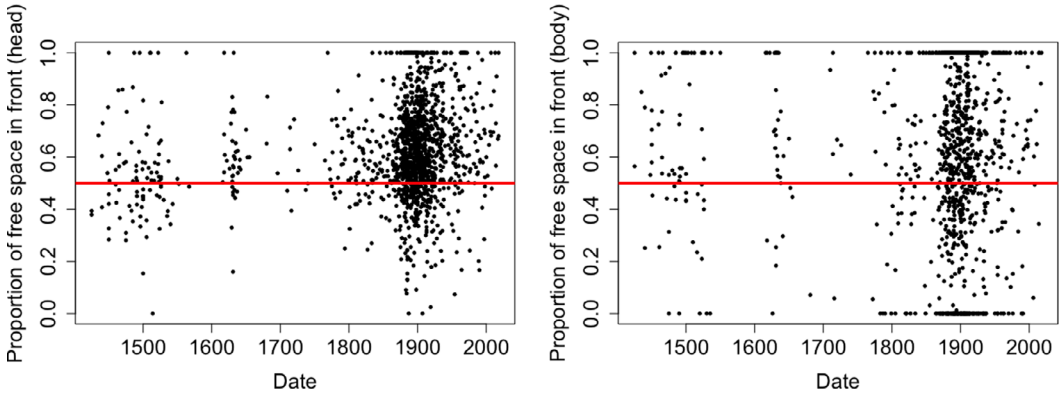

Fig. 4. Measures of the forward bias (i.e., proportion of the free space in front of the sitter), by date, for head (left), and body measures (right). The red line at $y = 0.5$ indicates the ratio at which there is an equal amount of space in front and behind the sitter (above the line are all portraits showing a forward bias).

that the more recent the portrait, the stronger its expression of the bias $b = 0.07$, 95% CI [0.04, 0.10], $t(1{,}097) = 4.48$, $p < .001$. For body measures, a simple linear regression ($F(1, 721) = 0.66$, $p = .417$, $R^2 < .01$), with date as an independent variable and strength of the bias (measured as the ratio of space in front of the sitter to the space behind the sitter) as the dependent variable failed to show a significant effect of date on how marked the forward bias was.

4. Discussion

We found evidence that the forward bias is at play in the spatial composition of single-sitter human profile-oriented portraits produced by European painters between the 15th and the 20th century. In one large dataset (1,831 paintings by 582 unique identified painters), painters tended to put more free space in front of, rather than behind, the sitters they depicted. Additionally, the sitters became more decentered over time.

The widespread presence of a forward bias was robust. Previous studies found some evidence of a forward bias in the production of a handful of painters (Bertamini et al., 2011). By finding evidence for a forward bias over a sample including productions by 582 unique painters, our results suggest that this bias in spatial composition was widespread. This is also particularly remarkable since it is goes against a cultural norm that favors centering sitters. The present study, using large-scale databases, is ideally suited for investigating production as it occurs in non-experimental, real-world conditions. Future research could address whether this forward bias also impacts the processing and aesthetical appreciation of those portraits. It should not be automatically assumed that all biases in production are caused by biases in reception. For instance, while there is evidence supporting a bias in favor of centering one of the sitter's eye in painters'

production of portraits (Tyler, 1998), there is no evidence for aesthetic preference for eye-centered portraits in the viewers (McManus & Thomas, 2007).

As detailed in Section 1, what motivated this study was the general observation that perceptual and cognitive systems throughout the animal kingdom take advantage of the typical directionality of animal body plan and its strong correlation with directionality of movement. In many animals including humans, this correlation extends to the directionality of perception and attention. Hence, in observing other agents, and in particular humans, it is quite generally the case that what might happen in front of them is more relevant than what might happen behind them. We speculated that this asymmetry might be a cognitive factor relevant to one type of cultural production, profile portraits. We predicted that there would be a forward bias in the composition of such portraits and that the strength of this forward bias would increase when the strength of the cultural norm of centering decreased. The evidence we produced confirms these predictions. Still, this evidence could be explained in more than one way.

Sammartino and Palmer (2012), for instance, drawing on Gibson's theory of affordances (Gibson, 1977), suggested that every object is surrounded by its "affordance space," which, in the case of agents, is more extended in front. Chen and colleagues hypothesized a "looking in the future" mechanism, in which viewers aim to keep a focus object in view while anticipating its action (Chen, Colombatto, & Scholl, 2018). Both Palmer and colleagues' and Chen and colleagues' interpretations of the forward bias (which they call "inward bias") are supported by their experimental evidence and are compatible with our historical evidence. Notably, they are more specific than the perspective offered by us in the introduction, in that they focus on the potential for action of agents represented. Given that our evidence consisted only of portraits of sitter looking straight ahead, we have no empirical ground to evaluate the relative importance of expectation of *forward movement* and expectation of *forward attention* in explaining the forward bias. These two factors, however, are correlated and complementary. They can be seen as aspects of a single explanation rather than as alternative explanations. Of course, the evidence from any single study could be interpreted in yet other ways. An anonymous reviewer pointed out, for instance, that our historical evidence is also compatible with the hypothesis that sitters tend to be depicted with their back closer to the edge of the picture or to an imaginary wall. To narrow down, at least provisionally, the wide range of possible hypotheses, it makes sense to focus on theoretically motivated hypotheses that can account for both the historical and experimental evidence already existing in the literature or that offer predictions to be tested in new experiments or through new analyses of the historical record.

The existence of a forward bias in profile portrait painting, a bias that was not codified and of which the artists themselves may not have been aware may lend itself to an explanation in terms of a "psychological factor of cultural attraction" (Miton et al., 2015; Sperber, 1996). The present study's goal was to illustrate how, in some cases at least, from a known cognitive disposition (here a disposition to attend more to what is in front of an agent rather than behind) one can formulate a testable prediction regarding features of cultural productions (here a forward bias in profile portraits). We believe that this logic

can be adapted to a variety of cognitive constraints and cultural phenomena (see Miton et al., 2015; Morin, 2013, 2018 for more examples).

The increase in frequency and in amplitude of the forward bias in historical time is best explained, we suggest, by taking into account two factors: a cultural-historical factor, the relaxation of a cultural norm of centering, and a psychological factor that affects the distribution of attention (leaving open the possibility that this psychological factor is itself culturally modulated). As long as a cultural norm of centering is active (whether intentionally enforced or not), this may both partially hinder and mask the expression of cognitive dispositions favoring less centered compositions.

This being the first systematic treatment of the topic, it could not but leave unaddressed not only many interesting issues but also the possibility of alternative explanations. While centering has been an explicit norm in the period we considered, for instance, it was not defined in terms of any precise measure as the one we used (i.e., based on how the free space is distributed around the sitter). Some painters may have secured centering in an intuitive way. Others may have used a variety of heuristics, for instance centering one feature of the sitter's body or face (e.g., eye or ear). The forward bias might be explained as an unintended consequence of this reliance on intuition or on specific heuristic tricks. If, however, intuitions and preferred heuristics had such a consequence, it might be because they themselves were influenced by the bias we described, in which case the two explanations would be complementary rather than mutually exclusive.

Another possibility, suggested by an anonymous reviewer, is that what we described as a forward bias is an effect of some tacit norm or convention, if not throughout the period we considered, at least since the 18th century, when explicit composition norms became less stringent. A convention-based explanation would predict the emergence of a manifestly dominant type; and, in the case of a *tacit* convention, it should have been the case that the people concerned (artists and their public) encountered, in the painting they saw, clear and sufficient evidence from which they would have been likely to infer the existence of this tacit convention. This is not what our evidence suggests.

We note, to begin with, that our results are more in line with a convention (that of centering) progressively losing its force than with a process of conventionalization of the forward bias. The proportion of centered portraits decreased over time, and overall decentering increased, suggesting that the convention in favor of centering held less and less sway. However, our evidence does not suggest that a new convention emerged favoring not just decentering, but more specifically, decentering with a forward bias. If that had been the case, the proportion of portraits with the forward bias among decentered portraits should also have increased. By contrast, the proportion of overall decentered portraits increased, including both portraits showing the forward bias and portraits exhibiting the opposite bias.

Our evidence gives further reasons to doubt that a process of tacit conventionalization of the forward bias could have taken place. In the whole period concerned, only a minority of portraits was done in profile. Only a minority of profile portraits was decentered, and, often, neither the fact nor the direction of decentering was so marked as to be obvious. It took us a large dataset and exact measurements to be able to demonstrate the

existence of a forward bias. The painters and public involved at the time saw many portraits in their lifetime, but relatively few profile portraits, fewer decentered ones, and even fewer ones with the forward bias. In other words, the evidence available for the existence of a forward bias in profile portrait paintings may well have been too scant and scattered for them to notice it and to interpret it as tacitly normative. Still, there arguably are norms or conventions that are not only tacit (in the sense of understood without being expressed) but unconscious and the forward bias could be a case in point. To discuss such a hypothesis and to make it precise enough to be testable, we would have to draw on theories of art (e.g., Gombrich, 1961; Goodman, 1976; Willats, 1997) and on theories of norms and conventions (e.g., Bicchieri, 2005; Lewis, 1969; Millikan, 2008), but this would go well beyond the limited ambition of this particular study.

More generally, psychological factors and social/conventional factors should not be thought of as two mutually exclusive sets that do not interact with one another. Psychological dispositions that have a strong biological basis can all the same be culturally modulated (as is obvious for the case of food preferences that are both based in the biology of the species and culturally variable—see Anderson, 2014). In this light, a probabilistic disposition to pay more attention to what is in front of agents rather than behind them may be culturally modulated and may, in particular, result in different pictorial practices across cultures. In some, it might result in explicit rules, like the recommendations of the contemporary photography handbooks to leave sufficient "lead room" or "look room" in front of people seen in profile. In some cultural context, this psychological disposition may result in implicit norms or conventions. Conversely, social norms or conventions may not be pure effects of historical and social factors independent of psychological factors (see Scott-Phillips, Blancke, & Heintz, 2018; Sperber, 1996). For instance, explicit cultural norms favoring centering in some pictorial compositions such as single-sitter portraits, which are found across different cultures and social contexts, may owe part of their widespread cultural success to a basic psychological appeal.

For a more detailed and precise account of the forward bias reported here, more experimental work on attention to the space surrounding an agent would be useful, and further historical factors regarding changes in tastes, conventions, techniques, formats, and the social role of portrait painting should be investigated across cultures. For a richer discussion of the theoretical relevance of such a study, it should be discussed together with other comparable cases (such as Morin, 2013).

Acknowledgments

We thank Robert Danyi and Hanna Hajnács for their help with data collection, and Christophe Heintz and Olivier Morin for their comments on earlier versions of this manuscript. The research reported in this manuscript was supported by a grant from the European Research Council (grant number: ERC-2013-SyG, Constructing Social Minds: Communication, Coordination and Cultural Transmission, ERC, grant agreement no

[609619]). Helena Miton was partially supported by a Complexity postdoctoral fellowship at the Santa Fe Institute.

Open Research badges

This article has earned Open Data badges. Data and materials are available at https://osf.io/6dsnx/?view_only=9835c19958754d5ab0672e7e54a9edae.

Note

1. Time-stamped registration: https://osf.io/2n5k8/?view_only=053af24b26aa467eb4ef7127bd24852c

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Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article:

Data S1. Supplementary materials: additional figures, details on methodological decisions, and additional analyses on ArtUK and WikiArt subsets.